BS EN 61784-2:2014

BSI Standards Publication

Industrial communication networks — Profiles

Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC 8802-3

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National foreword

This British Standard is the UK implementation of EN 61784-2:2014. It is identical to IEC 61784-2:2014. It supersedes BS EN 61784-2:2010 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AMT/7, Industrial communications: process measurement and control, including fieldbus.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Réseaux de communication industriels - Profils - Partie 2: Profils de bus de terrain supplémentaires pour les réseaux en temps réel basés sur l'ISO/CEI 8802-3 (CEI 61784-2:2014)

Industrielle Kommunikationsnetze - Profile - Teil 2: Zusätzliche Feldbusprofile für Echtzeitnetzwerke basierend auf ISO/IEC 8802-3 (IEC 61784-2:2014)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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Foreword

The text of document 65C/761/FDIS, future edition 3 of IEC 61784-2, prepared by SC 65C "Industrial networks" of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61784-2:2014.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-05-21
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-08-21

This document supersedes EN 61784-2:2010.

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Endorsement notice

The text of the International Standard IEC 61784-2:2014 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 61010	series	Safety requirements for electrical equipment for measurement, control and laboratory use	EN 61010	series
IEC 61131-2	-	Programmable controllers - Part 2: Equipment requirements and tests	EN 61131-2	-
IEC 61158	series	Industrial communication networks - Fieldbus specifications	EN 61158	series
IEC 61158-1	2014	Industrial communication networks - Fieldbus specifications - Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series	EN 61158-1	2014
IEC 61158-2	2014	Industrial communication networks - Fieldbus specifications - Part 2: Physical layer specification and service definition	EN 61158-2	2014
IEC 61158-3-2	2014	Industrial communication networks - Fieldbus specifications - Part 3-2: Data-link layer service definition - Type 2 elements	EN 61158-3-2	2014
IEC 61158-3-4	2014	Industrial communication networks - Fieldbus specifications - Part 3-4: Data-link layer service definition - Type 4 elements	EN 61158-3-4	2014
IEC 61158-3-11	2007	Industrial communication networks - Fieldbus specifications - Part 3-11: Data-link layer service definition - Type 11 elements	EN 61158-3-11	2008
IEC 61158-3-12	2014	Industrial communication networks - Fieldbus specifications - Part 3-12: Data-link layer service definition - Type 12 elements	EN 61158-3-12	2014

Publication	Year	Title	EN/HD	Year
IEC 61158-3-13	2014	Industrial communication networks - Fieldbus specifications - Part 3-13: Data link layer service definition - Type 13 elements	EN 61158-3-13	2014
IEC 61158-3-14	2014	Industrial communication networks - Fieldbus specifications - Part 3-14: Data-link layer service definition - Type 14 elements	EN 61158-3-14	2014
IEC 61158-3-17	2007	Industrial communication networks - Fieldbus specifications - Part 3-17: Data-link layer service definition - Type 17 elements	EN 61158-3-17	2008
IEC 61158-3-19	2014	Industrial communication networks - Fieldbus specifications - Part 3-19: Data-link layer service definition - Type 19 elements	EN 61158-3-19	2014
IEC 61158-3-21	2010	Industrial communication networks - Fieldbus specifications - Part 3-21: Data-link layer service definition - Type 21 elements	EN 61158-3-21	2012
IEC 61158-3-22	2014	Industrial communication networks - Fieldbus specifications - Part 3-22: Data-link layer service definition - Type 22 elements	EN 61158-3-22	2014
IEC 61158-4-2	2014	Industrial communication networks - Fieldbus specifications - Part 4-2: Data-link layer protocol specification - Type 2 elements	EN 61158-4-2	[1)]
IEC 61158-4-4	2014	Industrial communication networks - Fieldbus specifications - Part 4-4: Data-link layer protocol specification - Type 4 elements	EN 61158-4-4	[1)]
IEC 61158-4-11	2014	Industrial communication networks - Fieldbus specifications - Part 4-11: Data-link layer protocol specificationn - Type 11 elements	EN 61158-4-11	[1)]
IEC 61158-4-12	2014	Industrial communication networks - Fieldbus specifications - Part 4-12: Data-link layer protocol specification - Type 12 elements	EN 61158-4-12	[1)]
IEC 61158-4-13	2014	Industrial communication networks - Fieldbus specifications - Part 4-13: Data-link layer protocol specification - Type 13 elements	EN 61158-4-13	[1)]
IEC 61158-4-14	2014	Industrial communication networks - Fieldbus specifications - Part 4-14: Data-link layer protocol specification - Type 14 elements	EN 61158-4-14	[1)]

1) To be published.

Publication	Year	Title	EN/HD	Year
IEC 61158-4-17	2007	Industrial communication networks - Fieldbus specifications - Part 4-17: Data-link layer protocol specification - Type 17 elements	EN 61158-4-17	2008
IEC 61158-4-19	2014	Industrial communication networks - Fieldbus specifications - Part 4-19: Data-link layer protocol specification - Type 19 elements	EN 61158-4-19	[1)]
IEC 61158-4-21	2010	Industrial communication networks - Fieldbus specifications - Part 4-21: Data-link layer protocol specification - Type 21 elements	EN 61158-4-21	2012
IEC 61158-4-22	2014	Industrial communication networks - Fieldbus specifications - Part 4-22: Data-link layer protocol specification - Type 22 elements	EN 61158-4-22	[1)]
IEC 61158-5-2	2014	Industrial communication networks - Fieldbus specifications - Part 5-2: Application layer service definition - Type 2 elements	EN 61158-5-2	2014
IEC 61158-5-4	2014	Industrial communication networks - Fieldbus specifications - Part 5-4: Application layer service definition - Type 4 elements	EN 61158-5-4	2014
IEC 61158-5-10	2014	Industrial communication networks - Fieldbus specifications - Part 5-10: Application layer service definition - Type 10 elements	EN 61158-5-10	2014
IEC 61158-5-11	2007	Industrial communication networks - Fieldbus specifications - Part 5-11: Application layer service definition - Type 11 elements	EN 61158-5-11	2008
IEC 61158-5-12	2014	Industrial communication networks - Fieldbus specifications - Part 5-12: Application layer service definition - Type 12 elements	EN 61158-5-12	2014
IEC 61158-5-13	2014	Industrial communication networks - Fieldbus specifications - Part 5-13: Application layer service definition - Type 13 elements	EN 61158-5-13	2014
IEC 61158-5-14	2014	Industrial communication networks - Fieldbus specifications - Part 5-14: Application layer service definition - Type 14 elements	EN 61158-5-14	2014
IEC 61158-5-15	2010	Industrial communication networks - Fieldbus specifications - Part 5-15: Application layer service definition - Type 15 elements	EN 61158-5-15	2012
IEC 61158-5-17	2007	Industrial communication networks - Fieldbus specifications - Part 5-17: Application layer service definition - Type 17 elements	EN 61158-5-17	2008

Publication	Year	Title	EN/HD	Year
IEC 61158-5-19	2014	Industrial communication networks - Fieldbus specifications - Part 5-19: Application layer service definition - Type 19 elements	EN 61158-5-19	2014
IEC 61158-5-21	2010	Industrial communication networks - Fieldbus specifications - Part 5-21: Application layer service definition - Type 21 elements	EN 61158-5-21	2012
IEC 61158-5-22	2014	Industrial communication networks - Fieldbus specifications - Part 5-22: Application layer service definition - Type 22 elements	EN 61158-5-22	2014
IEC 61158-5-23	2014	Industrial communication networks - Fieldbus specifications - Part 5-23: Application layer service definition - Type 23 elements	EN 61158-5-23	2014
IEC 61158-6-2	2014	Industrial communication networks - Fieldbus specifications - Part 6-2: Application layer protocol specification - Type 2 elements	EN 61158-6-2	1)
IEC 61158-6-4	2014	Industrial communication networks - Fieldbus specifications - Part 6-4: Application layer protocol specification - Type 4 elements	EN 61158-6-4	1)
IEC 61158-6-10	2014	Industrial communication networks - Fieldbus specifications - Part 6-10: Application layer protocol specification - Type 10 elements	EN 61158-6-10	1)
IEC 61158-6-11	2007	Industrial communication networks - Fieldbus specifications - Part 6-11: Application layer protocol specification - Type 11 elements	EN 61158-6-11	2008
IEC 61158-6-12	2014	Industrial communication networks - Fieldbus specifications - Part 6-12: Application layer protocol specification - Type 12 elements	EN 61158-6-12	1)
IEC 61158-6-13	2014	Industrial communication networks - Fieldbus specifications - Part 6-13: Application layer protocol specification - Type 13 elements	EN 61158-6-13	1)
IEC 61158-6-14	2014	Industrial communication networks - Fieldbus specifications - Part 6-14: Application layer protocol specification - Type 14 elements	EN 61158-6-14	1)
IEC 61158-6-15	2010	Industrial communication networks - Fieldbus specifications - Part 6-15: Application layer protocol specification - Type 15 elements	EN 61158-6-15	2012
IEC 61158-6-17	2007	Industrial communication networks - Fieldbus specifications - Part 6-17: Application layer protocol specification - Type 17 elements	EN 61158-6-17	2008

Publication	Year	Title	EN/HD	Year
IEC 61158-6-19	2014	Industrial communication networks - Fieldbus specifications - Part 6-19: Application layer protocol specification - Type 19 elements	EN 61158-6-19	[1)]
IEC 61158-6-21	2010	Industrial communication networks - Fieldbus specifications - Part 6-21: Application layer protocol specification - Type 21 elements	EN 61158-6-21	2012
IEC 61158-6-22	2014	Industrial communication networks - Fieldbus specifications - Part 6-22: Application layer protocol specification - Type 22 elements	EN 61158-6-22	[1)]
IEC 61158-6-23	2014	Industrial communication networks - Fieldbus specifications - Part 6-23: Application layer protocol specification - Type 23 elements	EN 61158-6-23	[1)]
IEC 61588	2009	Precision clock synchronization protocol for networked measurement and control systems	-	-
IEC 61784-1	2014	Industrial communication networks - Profiles - Part 1: Fieldbus profiles	EN 61784-1	[1)]
IEC 61784-5-2	2013	Industrial communication networks - Profiles - Part 5-2: Installation of fieldbuses - Installation profiles for CPF 2	EN 61784-5-2	2013
IEC 61784-5-3	2013	Industrial communication networks - Profiles - Part 5-3: Installation of fieldbuses - Installation profiles for CPF 3	EN 61784-5-3	2013
IEC 61784-5-6	2013	Industrial communication networks - Profiles - Part 5-6: Installation of fieldbuses - Installation profiles for CPF 6	EN 61784-5-6	2013
IEC 61784-5-8	2013	Industrial communication networks - Profiles - Part 5-8: Installation of fieldbuses - Installation profiles for CPF 8	EN 61784-5-8	2013
IEC 61784-5-11	2013	Industrial communication networks - Profiles - Part 5-11: Installation of fieldbuses - Installation profiles for CPF 11	EN 61784-5-11	2013
IEC 61800	series	Adjustable speed electrical power drive systems	EN 61800	series
IEC 61918 (mod) -	2013 -	Industrial communication networks - Installation of communication networks in industrial premises	EN 61918 + AC	2013 2014
ISO/IEC 2382-16	1996	Information technology - Vocabulary - Part 16: Information theory	-	-

Publication	Year	Title	EN/HD	Year
ISO/IEC 7498-1	-	Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model	-	-
ISO/IEC 8802-2	-	Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 2: Logical link control	-	-
ISO/IEC 8802-3	2000	Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications	-	-
ISO/IEC/IEEE 8802-11	-	Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications	-	-
ISO/IEC 11801 + A1 + A2	2002 2008 2010	Information technology - Generic cabling for customer premises	- - -	- - -
ISO 15745-3	-	Industrial automation systems and integration - Open systems application integration framework - Part 3: Reference description for IEC 61158 based control systems	-	-
ISO 15745-4 + A1	2003 2006	Industrial automation systems and integration - Open systems application integration framework - Part 4: Reference description for Ethernet-based control systems	- -	- -
IEEE Std 802	2001	IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture	-	-
IEEE 802.1AB	-	IEEE Standard for Local and Metropolitan Area Networks - Station and Media Access Control Connectivity Discovery	-	-
IEEE 802.1AS	2011	IEEE Standard for Local and Metropolitan Area Networks - Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks	-	-

Publication	Year	Title	EN/HD	Year
IEEE 802.1D	2004	IEEE Standard for Local and Metropolitan Area Networks - Media Access Control (MAC) Bridges	-	-
IEEE 802.1Q	2011	IEEE Standard for Local and metropolitan area networks - Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks	-	-
IEEE 802.3	2008	IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications	-	-
IEEE 802.11	2007	IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications	-	-
IEEE Std 802.15.1	-	IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements. - Part 15.1: Wireless medium access control (MAC) and physical layer (PHY) specifications for wireless personal area networks (WPANs)	-	-
IETF RFC 768	-	User Datagram Protocol	-	-
IETF RFC 791	-	Internet Protocol	-	-
IETF RFC 792	-	Internet Control Message Protocol	-	-
IETF RFC 793	-	Transmission Control Protocol	-	-
IETF RFC 826	-	Ethernet Address Resolution Protocol - or - Converting Network Protocol Addresses to 48.bit Ethernet Address for Transmission on Ethernet Hardware	-	-
IETF RFC 894	-	A Standard for the Transmission of IP Datagrams over Ethernet Networks	-	-
IETF RFC 1034	-	Domain names - concepts and facilities	-	-
IETF RFC 1112	-	Host Extensions for IP Multicasting	-	-
IETF RFC 1122	-	Requirements for Internet Hosts - Communication Layers	-	-
IETF RFC 1123	-	Requirements for Internet Hosts - Application and Support	-	-
IETF RFC 1127	-	Perspective on the Host Requirements RFCs	-	-

Publication	Year	Title	EN/HD	Year
IETF RFC 1157	-	Simple Network Management Protocol (SNMP)	-	-
IETF RFC 1213	-	Management Information Base for Network Management of TCP/IP-based Internets: MIB-II	-	-
IETF RFC 1305	-	Network Time Protocol (Version 3) Specification, Implementation and Analysis	-	-
IETF RFC 2131	-	Dynamic Host Configuration Protocol	-	-
IETF RFC 2236	-	Internet Group Management Protocol, Version 2	-	-
IETF RFC 2544	-	Benchmarking Methodology for Network Interconnect Devices	-	-
IETF RFC 2988	-	Computing TCP's Retransmission Timer	-	-
IETF RFC 4836	-	Definitions of Managed Objects for IEEE 802.3 Medium Attachment Units (MAUs)	-	-
OSF CAE Specification C706	-	Technical Standard DCE1.1: Remote Procedure Call	-	-

CONTENTS

INTRODUCTION

This part of IEC 61784 provides additional Communication Profiles (CP) to the existing Communication Profile Families (CPF) of IEC 61784-1 and additional CPFs with one or more CPs. These profiles meet the industrial automation market objective of identifying Real-Time Ethernet (RTE) communication networks coexisting with ISO/IEC 8802-3 or IEEE 802.3 – commonly known as Ethernet. These RTE communication networks use provision from ISO/IEC 8802-3 for the lower communication stack layers and additionally provide more predictable and reliable real-time data transfer and means for support of precise synchronization of automation equipment.

More specifically, these profiles help to correctly state the compliance of RTE communication networks with ISO/IEC 8802-3 or IEEE 802.3, and to avoid the spreading of divergent implementations.

Adoption of Ethernet technology for industrial communication between controllers and even for communication with field devices promotes use of Internet technologies in the field area. This availability would be unacceptable if it causes the loss of features required in the field area for industrial communication automation networks, such as:

- real-time,
- synchronized actions between field devices like drives,
- efficient, frequent exchange of very small data records.

These new RTE profiles may take advantage of the improvements of Ethernet networks in terms of transmission bandwidth and network span.

Another implicit but essential requirement is that the typical Ethernet communication capabilities, as used in the office world, are fully retained, so that the software involved remains applicable.

The market is in need of several network solutions, each with different performance characteristics and functional capabilities, matching the diverse application requirements. RTE performance indicators (see Clause 5), which values will be provided with RTE devices based on communication profiles specified in this part of IEC 61784, enable the user to match network devices with application dependant performance requirements of an RTE network.

Subclause 5.1 specifies basic principles of performance indicators required to express RTE performance of a CP. Subclause 5.2 describes the view of application requirements. An application-dependant class could be used to find out a suitable CP. Clause 4 specifies how conformance of a device to the CPF or CP should be stated.

INDUSTRIAL COMMUNICATION NETWORKS – PROFILES –

Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC 8802-3

1 Scope

This part of IEC 61784 specifies

- performance indicators supporting classification schemes for Real-Time Ethernet (RTE) requirements;
- profiles and related network components based on ISO/IEC 8802-3 or IEEE 802.3, IEC 61158 series, and IEC 61784-1;
- RTE solutions that are able to run in parallel with ISO/IEC 8802-3 or IEEE 802.3 based applications.

These communication profiles are called Real-Time Ethernet communication profiles.

NOTE The RTE communication profiles use ISO/IEC 8802-3 or IEEE 802.3 communication networks and its related network components or IEC 61588 and may in some cases amend those standards to obtain RTE features.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE All parts of the IEC 61158 series, as well as IEC 61784-1 and IEC 61784-2 are maintained simultaneously. Cross-references to these documents within the text therefore refer to the editions as dated in this list of normative references.

IEC 61010 (all parts), *Safety requirements for electrical equipment for measurement, control, and laboratory use*

IEC 61131-2, *Programmable controllers – Part 2: Equipment requirements and tests*

IEC 61158 (all parts), *Industrial communication networks – Fieldbus specifications*

IEC 61158-1:2014, *Industrial communication networks – Fieldbus specifications – Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series*

IEC 61158-2:2014, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 61158-3-2:2014, *Industrial communication networks – Fieldbus specifications – Part 3-2: Data-link layer service definition – Type 2 elements*

IEC 61158-3-4:2014, *Industrial communication networks – Fieldbus specifications – Part 3-4: Data-link layer service definition – Type 4 elements*

IEC 61158-3-11:2007, *Industrial communication networks – Fieldbus specifications – Part 3-11: Data-link layer service definition – Type 11 elements*

IEC 61158-3-12:2014, *Industrial communication networks – Fieldbus specifications – Part 3-12: Data-link layer service definition – Type 12 elements*

IEC 61158-3-13:2014, *Industrial communication networks – Fieldbus specifications – Part 3-13: Data-link layer service definition – Type 13 elements*

IEC 61158-3-14:2014, *Industrial communication networks – Fieldbus specifications – Part 3-14: Data-link layer service definition – Type 14 elements*

IEC 61158-3-17:2007, *Industrial communication networks – Fieldbus specifications – Part 3-17: Data-link layer service definition – Type 17 elements*

IEC 61158-3-19:2014, *Industrial communication networks – Fieldbus specifications – Part 3-19: Data-link layer service definition – Type 19 elements*

IEC 61158-3-21:2010, *Industrial communication networks – Fieldbus specifications – Part 3-21: Data-link layer service definition – Type 21 elements*

IEC 61158-3-22:2014, *Industrial communication networks – Fieldbus specifications – Part 3-22: Data-link layer service definition – Type 22 elements*

IEC 61158-4-2:2014, *Industrial communication networks – Fieldbus specifications – Part 4-2: Data-link layer protocol specification – Type 2 elements*

IEC 61158-4-4:2014, *Industrial communication networks – Fieldbus specifications – Part 4-4: Data-link layer protocol specification – Type 4 elements*

IEC 61158-4-11:2014, *Industrial communication networks – Fieldbus specifications – Part 4-11: Data-link layer protocol specification – Type 11 elements*

IEC 61158-4-12:2014, *Industrial communication networks – Fieldbus specifications – Part 4-12: Data-link layer protocol specification – Type 12 elements*

IEC 61158-4-13:2014, *Industrial communication networks – Fieldbus specifications – Part 4-13: Data-link layer protocol specification – Type 13 elements*

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IEC 61158-4-17:2007, *Industrial communication networks – Fieldbus specifications – Part 4-17: Data-link layer protocol specification – Type 17 elements*

IEC 61158-4-19:2014, *Industrial communication networks – Fieldbus specifications – Part 4-19: Data-link layer protocol specification – Type 19 elements*

IEC 61158-4-21:2010, *Industrial communication networks – Fieldbus specifications – Part 4-21: Data-link layer protocol specification – Type 21 elements*

IEC 61158-4-22:2014, *Industrial communication networks – Fieldbus specifications – Part 4-22: Data-link layer protocol specification – Type 22 elements*

IEC 61158-5-2:2014, *Industrial communication networks – Fieldbus specifications – Part 5-2: Application layer service definition – Type 2 elements*

IEC 61158-5-4:2014, *Industrial communication networks – Fieldbus specifications – Part 5-4: Application layer service definition – Type 4 elements*

IEC 61158-5-10:2014, *Industrial communication networks – Fieldbus specifications – Part 5-10: Application layer service definition – Type 10 elements*

IEC 61158-5-11:2007, *Industrial communication networks – Fieldbus specifications – Part 5-11: Application layer service definition – Type 11 elements*

IEC 61158-5-12:2014, *Industrial communication networks – Fieldbus specifications – Part 5-12: Application layer service definition – Type 12 elements*

IEC 61158-5-13:2014, *Industrial communication networks – Fieldbus specifications – Part 5-13: Application layer service definition – Type 13 elements*

IEC 61158-5-14:2014, *Industrial communication networks – Fieldbus specifications – Part 5-14: Application layer service definition – Type 14 elements*

IEC 61158-5-15:2010, *Industrial communication networks – Fieldbus specifications – Part 5-15: Application layer service definition – Type 15 elements*

IEC 61158-5-17:2007, *Industrial communication networks – Fieldbus specifications – Part 5-17: Application layer service definition – Type 17 elements*

IEC 61158-5-19:2014, *Industrial communication networks – Fieldbus specifications – Part 5-19: Application layer service definition – Type 19 elements*

IEC 61158-5-21:2010, *Industrial communication networks – Fieldbus specifications – Part 5-21: Application layer service definition – Type 21 elements*

IEC 61158-5-22:2014, *Industrial communication networks – Fieldbus specifications – Part 5-22: Application layer service definition – Type 22 elements*

IEC 61158-5-23:2014, *Industrial communication networks – Fieldbus specifications – Part 5-23: Application layer service definition – Type 23 elements*

IEC 61158-6-2:2014, *Industrial communication networks – Fieldbus specifications – Part 6-2: Application layer protocol specification – Type 2 elements*

IEC 61158-6-4:2014, *Industrial communication networks – Fieldbus specifications – Part 6-4: Application layer protocol specification – Type 4 elements*

IEC 61158-6-10:2014, *Industrial communication networks – Fieldbus specifications – Part 6-10: Application layer protocol specification – Type 10 elements*

IEC 61158-6-11:2007, *Industrial communication networks – Fieldbus specifications – Part 6-11: Application layer protocol specification – Type 11 elements*

IEC 61158-6-12:2014, *Industrial communication networks – Fieldbus specifications – Part 6-12: Application layer protocol specification – Type 12 elements*

IEC 61158-6-13:2014, *Industrial communication networks – Fieldbus specifications – Part 6-13: Application layer protocol specification – Type 13 elements*

IEC 61158-6-14:2014, *Industrial communication networks – Fieldbus specifications – Part 6-14: Application layer protocol specification – Type 14 elements*

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IEC 61158-6-19:2014, *Industrial communication networks – Fieldbus specifications – Part 6-19: Application layer protocol specification – Type 19 elements*

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IEC 61158-6-22:2014, *Industrial communication networks – Fieldbus specifications – Part 6-22: Application layer protocol specification – Type 22 elements*

IEC 61158-6-23:2014, *Industrial communication networks – Fieldbus specifications – Part 6-23: Application layer protocol specification – Type 23 elements*

IEC 61588:2009, *Precision clock synchronization protocol for networked measurement and control systems*

IEC 61784-1:2014, *Industrial communication networks – Profiles – Part 1: Fieldbus profiles*

IEC 61784-5-2:2013, *Industrial communication networks – Profiles – Part 5-2: Installation of fieldbuses – Installation profiles for CPF 2*

IEC 61784-5-3:2013, *Industrial communication networks – Profiles – Part 5-3: Installation of fieldbuses – Installation profiles for CPF 3*

IEC 61784-5-6:2013, *Industrial communication networks – Profiles – Part 5-6: Installation of fieldbuses – Installation profiles for CPF 6*

IEC 61784-5-8:2013, *Industrial communication networks – Profiles – Part 5-8: Installation of fieldbuses – Installation profiles for CPF 8*

IEC 61784-5-11:2013, *Industrial communication networks – Profiles – Part 5-11: Installation of fieldbuses – Installation profiles for CPF 11*

IEC 61918:2013, *Industrial communication networks – Installation of communication networks in industrial premises*

IEC 61800 (all parts), *Adjustable speed electrical power drive systems*

ISO/IEC 2382-16:1996, *Information technology – Vocabulary – Part 16: Information theory*

ISO/IEC 7498-1, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model*

ISO/IEC 8802-2, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 2: Logical link control*
Corrigendum 1

ISO/IEC 8802-3:2000, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

ISO/IEC 8802-11, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications*

ISO/IEC 11801:2002, *Information technology – Generic cabling for customer premises*[1]
Amendment 1: 2008
Amendment 2:2010

ISO 15745-3, *Industrial automation systems and integration – Open systems application integration framework – Part 3: Reference description for IEC 61158-based control systems*

ISO 15745-4:2003, *Industrial automation systems and integration – Open systems application integration framework – Part 4: Reference description for Ethernet-based control systems*
Amendment 1:2006, *PROFINET profiles*

IEEE 802-2001, *IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture*

IEEE 802.1AB, *IEEE Standard for Local and metropolitan area networks Station and Media Access Control Connectivity Discovery*

IEEE 802.1AS-2011, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – IEEE standard for Local and metropolitan area networks – Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks*

IEEE 802.1D-2004, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – IEEE standard for local and metropolitan area networks – Common specifications – Media access control (MAC) Bridges*

IEEE 802.1Q-2011 *IEEE Standard for Information technology – Telecommunications and information exchange between systems – IEEE standard for Local and metropolitan area networks – Virtual bridged local area networ*ks

IEEE 802.3-2008, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*

NOTE Compliance with future editions of this standard will need checking.

IEEE Std 802.11-2007, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks– Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*

IEEE Std 802.15.1, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15: Wireless medium access control (MAC) and physical layer (PHY) specifications for wireless personal area networks (WPANs)*

IETF RFC 768, *User Datagram Protocol*, available at <http://www.ietf.org>

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[1] There exisits a consolidated edition 2.2:2011 that compreises ISO/IEC 11801:2002, its Amendment 1:2008 and its Amendment 2:2010.

IETF RFC 791, *Internet Protocol*, available at <http://www.ietf.org>

IETF RFC 792, *Internet Control Message Protocol*, available at <http://www.ietf.org>

IETF RFC 793, *Transmission Control Protocol*, available at <http://www.ietf.org>

IETF RFC 826, *Ethernet Address Resolution Protocol*, available at <http://www.ietf.org>

IETF RFC 894, *A standard for the Transmission of IP Datagrams over Ethernet Networks*, available at <http://www.ietf.org>

IETF RFC 1034, *Domain names – concepts and facilities*; available at <http://www.ietf.org>

IETF RFC 1112, *Host Extensions for IP Multicasting*, available at <http://www.ietf.org>

IETF RFC 1122, *Requirements for Internet Hosts – Communication Layers*, available at <http://www.ietf.org>

IETF RFC 1123, *Requirements for Internet Hosts – Application and Support,* available at <http://www.ietf.org>

IETF RFC 1127, *A Perspective on the Host Requirements RFCs*, available at <http://www.ietf.org>

IETF RFC 1157, *Simple Network Management Protocol (SNMP)*, available at <http://www.ietf.org>

IETF RFC 1213, *Management Information Base for Network Management of TCP/IP-based internets: MIB-II*, available at <http://www.ietf.org>

IETF RFC 1305, *Network Time Protocol (Version 3)*, available at <http://www.ietf.org>

IETF RFC 2131, *Dynamic Host Configuration Protocol*, available at <http://www.ietf.org>

IETF RFC 2236, *Internet Group Management Protocol, Version 2*, available at <http://www.ietf.org>

IETF RFC 2544, *Benchmarking Methodology for Network Interconnect Devices*, available at <http://www.ietf.org>

IETF RFC 2988, *Computing TCP's Retransmission Timer*, available at <http://www.ietf.org>

IETF RFC 4836, *Definitions of Managed Objects for IEEE 802.3 Medium Attachment Units (MAUs)*, available at <http://www.ietf.org>

Open Software Foundation (OSF): C706, *CAE Specification DCE1.1: Remote Procedure Call*, available at <http://www.opengroup.org/onlinepubs/9629399/toc.htm>

3 Terms, definitions, abbreviated terms, acronyms, and conventions

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 8802-3, IEEE 802, IEEE 802.1AB, IEEE 802.1AS, IEEE 802.1D, IEEE 802.1Q and IEEE 802.3, as well as the following, apply.

3.1.1
active network
network in which data transmission between non-immediately-connected devices is dependent on active elements within those intervening devices that form the connection path

[SOURCE: IEC 61918:2013, 3.1.3]

3.1.2
communication cycle
<CPF 16>
fixed time period between two master synchronization telegrams

3.1.3
cyclic
repetitive in a regular manner

3.1.4
domain
<CPF 10>
part of the network consisting of one or two subnetwork(s)

Note 1 to entry: Two subnetworks are required to compose a dual-redundant network, and each end-station in the domain is connected to both of the subnetworks.

3.1.5
end-station
a system attached to a network that is an initial source or a final destination of MAC frames transmitted across that network

Note 1 to entry: A network layer router is, from the perspective of the network, an end-station. A switch, in its role of forwarding MAC frames from one link to another, is not an end-station.

3.1.6
field area
place in a manufacturing or process site where field devices are located

3.1.7
frame
a unit of data transmission on an ISO/IEC 8802-3 MAC (Media Access Control) that conveys a protocol data unit (PDU) between MAC service users

[SOURCE: IEEE 802.1Q-2011]

3.1.8
identification number
IDN
<CPF 16>
designation of operating data under which a data block is preserved with its attribute, name, unit, minimum and maximum input values, and the data

3.1.9
IP channel
<CPF 16>
defined time slot within the communication cycle, which passes ISO/IEC 8802-3 Ethernet protocol frames (non-real-time communication)

3.1.10
jitter
temporal change in clock signal or temporal change in otherwise regular event

3.1.11
linear topology
topology where the nodes are connected in series, with two nodes each connected to only one other node and all others each connected to two other nodes (that is, connected in the shape of a line)

[SOURCE: IEC 61918:2013, 3.1.44]

3.1.12
link
transmission path between two adjacent nodes

[SOURCE: derived from ISO/IEC 11801]

3.1.13
logical double line
<CPF 18>
sequence of root device and all ordinary devices processing the DLPDU in forward and backward direction

3.1.14
master
<CPF 16>
node which assigns the other nodes the right to transmit

3.1.15
message
ordered series of octets intended to convey information

[SOURCE: derived from ISO/IEC 2382-16:1996,16.02.01]

Note 1 to entry: Normally used to convey information between peers at the application layer.

3.1.16
MDT0 telegram
<CPF 16>
telegram, in which the master transmits its synchronization data, as well as parts or all of its real-time data, to the slaves

3.1.17
node
network entity connected to one or more links

Note 1 to entry: A node may be either a switch, an end-station or an RTE end-station.

3.1.18
packet
logical grouping of information used to describe a unit of data at any layer to convey the upper layer user data to its peer layer

Note 1 to entry: A packet is identical to the PDU at each layer in terms of the OSI reference model. A data-link layer packet is a frame.

3.1.19
real-time
the ability of a system to provide a required result in a bounded time

3.1.20
real-time communication
transfer of data in real time

3.1.21
Real-Time Ethernet
RTE
ISO/IEC 8802-3 or IEEE 802.3 based network that includes real-time communication

Note 1 to entry: Other communication can be supported, providing the real-time communication is not compromised.

Note 2 to entry: This definition is dedicated but not limited to ISO/IEC 8802-3. It could be applicable to other IEEE 802 specifications, for example IEEE 802.11.

3.1.22
real time frame line
RTFL
<CPF 18>
communication model with devices communicating in a logical double line

3.1.23
real time frame network
RTFN
<CPF 18>
communication model with devices communicating in a switched network

3.1.24
ring
active network where each node is connected in series to two other nodes

Note 1 to entry: Ring may also be referred to as loop.

[SOURCE: IEC 61918:2013, 3.1.63]

3.1.25
router
<CPF 10>
intermediate equipment that connects two or more subnetworks using a network layer relay function

3.1.26
RTE end device
device with at least one RTE end-station

3.1.27
RTE end-station
end-station with RTE capability

3.1.28
schedule
temporal arrangement of a number of related operations

3.1.29
star
network of three or more devices where all devices are connected to a central point

[SOURCE: IEC 61918:2013, 3.1.69, modified – "which may be active or passive" has been suppressed]

3.1.30
subnetwork
<CPF 10>
part of a network that does not contain any routers

Note 1 to entry: A subnetwork consists of end-stations, bridges and segments.

Note 2 to entry: Every end-station included in a subnetwork has the same IP network address.

3.1.31
switch
MAC bridge as defined in IEEE 802.1D

3.1.32
telegram
<CPF 16>
frame

3.2 Abbreviated terms and acronyms

AL	Application Layer
APDU	Application Protocol Data Unit
API	Application Process Identifier
AR	Application Relationship
ARP	Address Resolution Protocol
ASE	Application Service Elements
CP	Communication Profile [according to IEC 61784-1]
CPF	Communication Profile Family [according to IEC 61784-1]
CRC	Cyclic Redundancy Check
CSMA-CD	Carrier Sense Multiple Access with Collision Detection
DA	Destination MAC Address
DHCP	Dynamic Host Configuration Protocol (see RFC 2131)
DL	Data-Link layer (as a prefix)
DLL	DL-Layer
DNS	Domain Name Service
DUT	Device under test
ECSME	EPA Communication Scheduling Management Entity
FA	Factory Automation
FCS	Frame check sequence
FrameID	Frame Identificator (see IEC 61158-6-10)
GSD	General station description
HW	Hardware
IANA	Internet Assigned Numbers Authority
ICMP	Internet Control Message Protocol (see RFC 792)
ID	Identifier
IDN	IDentification Number
IETF	Internet Engineering Task Force
IO	Input Output
IP	Internet Protocol (see RFC 791)

IPv4	Internet Protocol version 4 (see RFC 791)
IRT	Isochronous RT
LAN	Local Area Network
LLC	Logical Link Control
LLDP	Link Layer Discovery Protocol (see IEEE 802.1AB)
MAC	Media Access Control
MAC	Media Access Control (see ISO/IEC 8802.3 or IEEE 802.3)
Mbit/s	Million bits per second
Moctets/s	Million octets per second
MCR	Multicast communication relation
MIB	Management Information base
MRP	Medium redundancy protocol
MRPD	Media redundancy for planned duplication
ms	milli seconds
n.a.	Not applicable
NoS	Number of Switches
NRT	Non-real-time
PDU	Protocol Data Unit
PI	Performance indicator
ns	nano seconds
OID	Object Identifier (see IETF RFC 1157)
PDU	Protocol Data Unit
PhL	Physical Layer
Phy	PHY Physical layer entity sublayer (see ISO/IEC 8802.3 or IEEE 802.3)
PI	Performance indicator
pps	Packets per second
PTCP	Precision Transparent Clock Protocol
PTP	Precision Time Protocol [IEC 61588]
RPC	Remote Procedure Call
RSTP	Rapid Spanning Tree Algorithm and protocol (see IEEE 802.1D)
RT	Real-time
RTA	Real-time protocol acyclic
RTE	Real-time Ethernet
RT-Ethernet	Real-time Ethernet
RTFL	Real time frame line
RTFN	Real time frame network
RTO	Retransmission Time Out [according to RFC 2988 – Computing TCP's Retransmission Timer]
RTPS	Real-Time Publish-Subscribe
SERCOS	SErial Real time COmmunication System
SNMP	Simple Network Management Protocol (see IETF RFC 1213)
TCC	Time-Critical Cyclic
TCP	Transmission Control Protocol (see IETF RFC 793)

TOS Type of Service
UDP User Datagram Protocol (see IETF RFC 768)
VLAN Virtual LAN

3.3 Symbols

3.3.1 CPF 2 symbols

Symbol	Definition	Unit
APDUsize	Size of the application protocol data unit per CP 2/2 connection	octets
CD	Cable segment delay	µs
CL	Cable segment length	m
DT	Delivery time	µs
EN_NRTE_PR	End-station non-RTE packet rate per CP 2/2 connection	pps
EN_RTE_PR	End-station RTE packet rate per CP 2/2 connection	pps
EN_PR	End-station packet rate	pps
EN_PR_MAX	End-station maximum packet rate	pps
EN_TNRTE_PR	End-station total non-RTE packet rate in pps	pps
EN_TRTE_PR	End-station total RTE packet rate	pps
k	Number of CP 2/2 connections supported by the end-station	–
m	Number of CR 2/2 non-RTE connections	–
n	Number of switches between sending and receiving end-stations	–
p	Number of CR 2/2 RTE connections	–
NRTE_BW	Non-RTE bandwidth	%
PD	Cable propagation delay	n/m
SD_r	Receiver stack delay	µs
SD_s	Sender stack delay	µs
SL	Switch latency	µs
SPD	Switch processing delay	µs
T_{x_packet}	Packet transmit time	µs

3.3.2 CPF 3 symbols

Symbol	Definition	Unit
Cd	Cable delay (see attribute cable_delay in IEC 61158–5–10)	s
Clt	Total cable length	m
cta_R	Application cycle time of the Receiver	s
cta_S	Application cycle time of the Sender	s
Ctc	Communication cycle time	s
Ctc	Communication cycle time	s
Data	Complete Ethernet frame	octets
data_request	Requested RTE throughput	octets/s
data_RTE	Actual RTE throughput	octets/s
DT	Delivery time	s
endStations	Number of end-stations	–
EthernetDataRate	Ethernet data rate of the network	Mbit/s
MAC_delay	Delay on MAC layer	s
NonRTE	Percentage of non-RTE bandwidth	%
NoS	Number of switches	–
Od	Other delays, e. g. signal forwarding in a ring	s
Pd	Propagation delay	s
Phy_R_delay	Phy delay on receiver side	s
Phy_S_delay	Phy delay on sender side	s
protocolRTE	Percentage of protocol time	s
Queue_delay	Queue delay in a switch	s
RM	Time needed for management functions to support redundancy	s
RR	Attribute *Reduction Ratio* (see IEC 61158–5–10)	–
SCF	Attribute *Send Clock Factor* (see IEC 61158–5–10)	–
STTr	Receiver stack traversal time including Phy and MAC	s
STTs	Sender stack traversal time including Phy and MAC	s
Throughput_RTE	Throughput RTE	octets/s
Time_synchron_accuracy	Time synchronization accuracy	s
Tt	Transfer time	s

3.3.3 CPF 4 symbols

Symbol	Definition	Unit
cd	Cable delay (Maximum on 100m)	μs
DT	Delivery time	μs
DTb	Delivery time, calculated by best-case values	μs
DTw	Delivery time, calculated by worst-case values	μs
FS	Number of frames allowed to be sent per second for one RTE end-station	–
NoAS	Number of accesses allowed per device per second	–
NoCEN	Number of RTE end-stations which can produce frames on the critical switch-to-switch link	–
NoNs[x]	Number of RTE end-stations connected to switch number x	–
NoNt	Number of RTE end-stations, in total	–
NoS	Number of switches in path from sender to receiver	–
pd	Propagation delay within a switch. Required minimum value	μs
QTES	Ethernet enforced quiet time on end-station to switch link	μs
QTSS	Ethernet enforced quiet time on switch-to-switch link	μs
STTr	Receiver stack transversal time including Phy and MAC	μs
STTs	Sender stack transversal time including Phy and MAC	μs
ttES	P-NET transfer time RTE end-station to switch (at maximum APDU size)	μs
ttESmin	P-NET transfer time RTE end-station to switch (at min APDU size)	μs
ttSS	P-NET transfer time switch-to-switch (at maximum APDU size)	μs

3.3.4 CPF 6 symbols

Symbol	Definition	Unit
DTLD	Total delivery time between a Type 8 slave and a Type 10 entity	μs
DT10	Delivery time of the Type 10 network	μs
Cta_M	Application cycle time of the mapping application in the linking-device	
M	Type 8 Master implementation factor	–
n	Number of data octets (user data; payload)	octets
sl8	Number of Type 8 slaves connected to the linking-device	–
T_{bit}	Nominal bit duration (see 27.2 in IEC 61158-2)	μs
t_S	Software processing time of the Type 8 master (application specific)	μs

3.3.5 CPF 10 symbols

Symbol	Definition	Unit
Cdly	Cable delay	µs
Clen	Cable length	m
Dlen	Length of the complete Ethernet frame	bit
DT	Delivery time	µs
DTlost1	maximum delivery time with one lost frame for communication between two end-stations belonging to the same domain	µs
DTlost2	maximum delivery time with one lost frame for communication between two end-stations belonging to different domains	µs
DTmax1	maximum delivery time for communication between two end-stations belonging to the same domain	µs
DTmax2	maximum delivery time for communication between two end-stations belonging to different domains	µs
NoS	Number of switches in path from sender to receiver	–
Spd	Switch delay under not congested condition	µs
STTr	Receiver stack transversal time including PhL, DLL and AP	µs
STTs	Sender stack transversal time including PhL, DLL and AP	µs
Trate	Transfer bit rate	Mbit/s

3.3.6 CPF 11 symbols

Symbol	Definition	Unit
BW_{CNT}	Bandwidth used both for the communication scheduling and the protocol overhead	%
BW_{NRT}	Bandwidth used for the non-RTE communications	%
BW_{RTE}	Bandwidth used for the RTE communications	%
cd	Cable delay	µs
cdl	Cable length total	km
ct	Cycle time	ms
data	Complete Ethernet frame	–
DT_H	Delivery time of the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC	ms
DT_L	Delivery time of the low-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC	ms
DT_M	Delivery time of the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC	ms
DV_{HS}	Total volume of the high-speed cyclic data	octets
DV_{LS}	Total volume of the low-speed cyclic data	octets
DV_{MS}	Total volume of the medium-speed cyclic data	octets
NoS	Number of switches	–
od	Other delays	µs
pd	Propagation delay	µs
STTs	Sender stack traversal time including Phy and MAC	µs
STTr	Receiver stack traversal time including Phy and MAC	µs

Symbol	Definition	Unit
T_h	The high-speed transmission time period – the basic cycle_time (ct) of the TCC data service	ms
T_{HS}	Total sum of the frame transmit time, in which the TCC data frame conveys the high-speed cyclic data	µs
T_l	The Low-speed transmission time period	ms
T_{LS}	Total sum of the frame transmit time, in which the TCC data frame conveys the Low-speed Cyclic data	µs
T_m	The Medium-speed transmission time period	ms
T_{MAC}	Time for the maintenance and control, in which a new end-station is solicited to join and the periodic time operation is controlled	µs
T_{MS}	Total sum of the frame transmit time, in which the TCC data frame conveys the medium-speed cyclic data	µs
T_{NRT}	Total sum of the frame transmit time, in which the frame, with the non-RTE data as a payload, is sent out of the end-station within the time period of T_h and is used for the standard Ethernet application on sporadic basis	µs
TR_{HS}	Throughput RTE of the high-speed cyclic data	Moctets/s
TR_{LS}	Throughput RTE of the low-speed cyclic data	Moctets/s
TR_{MS}	Throughput RTE of the medium-speed cyclic data	Moctets/s
TR_{RTE}	Throughput RTE, and the sum of TR_{HS}, TR_{LS} and TR_{MS}	Moctets/s
T_{RTE}	Total sum of the frame transmit time, in which the frame, with the RTE data as a payload of a fixed length, is sent out of the end-station within the time period of T_h	µs
T_{SCH}	Total sum of the frame transmit time for the transmission scheduling	µs
tt	Transfer time	µs

3.3.7 CPF 12 symbols

Symbol	Definition	Unit
l_{tc}	Total cable length	m
NoS	Number of slaves	
Pd	Propagation delay	µs
t_{cd}	Cable delay	µs/m
t_{cpdl}	Data copy delay within a slave	µs
t_{cycle}	Cycle time	µs
t_D	Delivery time	µs
t_{data}	Time to transmit the longest real-time Ethernet frame	µs

3.3.8 CPF 13 symbols

Symbol	Definition	Unit
B_{NRTE}	Non-RTE bandwidth	%
M	Network MTU (maximum transmission unit)	octets
N	Number of RTE end-stations processed in one communication cycle	–
T_A	Time reserved for non-RTE data within one communication cycle	µs
T_C	Communication cycle time	µs
T_D	Delivery time	µs

Symbol	Definition	Unit
$T_{FT,i}$	RTE frames transmission time for RTE end-station i	µs
T_{PR}	Processing time in the receiving end-station	µs
T_{PS}	Processing time in the sending end-station	µs
$T_{RD,i}$	Response delay of the RTE end-station i	µs
T_S	Communication cycle start delay	µs
$T_{SD,i}$	Sum of all delays of infrastructure components (switches, hubs, cabling) for the RTE end-station i	µs

3.3.9 CPF 14 symbols

Symbol	Definition	Unit
DT	Delivery time	µs
D_size	Data size	octets
LCable	Cable length	m
Ndata	Length of complete Ethernet frame	octets
NRTE_BW	Non-RTE bandwidth	%
NSwitch	Number of switches between end-stations	
RateofEthernet	Ethernet data rate	Mbit/s
RMData	Redundancy management data	octets
RTEData	Real-time data	octets
TApp_R	Receiver stack processing time including Phy and MAC	µs
TCable	Cable delay	µs
TD_Sw	Time delay in switch	µs
TEthernet_S	Sender traversal time through MAC and Phy based on ISO/IEC 8802-3	µs
ThroughputRTE	RTE throughput	octets/s
TQueue_S	Sender queuing delay	µs
TSData	Time synchronization data	octets
TStack_S	Sender stack processing time	µs
TSwitch	Switch delay	µs
TTrf_S	Transfer time for one octet	µs
T_wire	Time per octet on a wire segment	µs
STT_s	Stack traversal time of the sender	µs
STT_r	Stack traversal time of the receiver	µs

3.3.10 CPF 15 symbols

Symbol	Definition	Unit
D_size	Data size	octets
DT	Delivery time	µs
DT_lf	Delivery time when a frame is lost	µs
DT_lfh	Delivery time when a frame is lost and the configuration is reliable with heartbeat	µs
DT_lfp	Delivery time when a frame is lost and the configuration is reliable periodic	µs
DT_n	Delivery time for the NACK message	µs

Symbol	Definition	Unit
H	Period of the heartbeat, which is a configured parameter	μs
N_Sw	Number of switches between end-stations	–
RTO	TCP retransmission time out parameter	μs
STT_r	Stack traversal time of the receiver	μs
STT_r1	Part of the stack traversal time of the receiver that is independent of D-size	μs
STT_r2	Part of the stack traversal time of the receiver that depends linearly on D_size	μs
STT_s	Stack traversal time of the sender	μs
STT_s1	Part of the stack traversal time of the sender that is independent of D_size	μs
STT_s2	Part of the stack traversal time of the sender that depends linearly on D_size	μs
T	Period, which is a configured parameter	μs
T_wire	Time per octet on a wire segment	μs
TD_Sw	Time delay in switch	μs

3.3.11 CPF 16 symbols

Symbol	Definition	Unit
ac	Non-time based synchronization accuracy	ns
cd	Cable delay	μs/m
clt	Total cable length	m
ct	Cycle_time configured for the network segment	μs
data	Data to be transmitted in one cycle (including the complete Ethernet frame)	bit
DT	Delivery time	μs
fr	Frame runtime	μs
ma	Synchronization accuracy of the master device	μs
mct	Minimum cycle time	ms
N	Integer value	–
nf	Number of frames	–
nn	Number of nodes	–
pd	Propagation delay (signal delay) of a forwarding node	μs
sa	Synchronization accuracy of one slave device	μs
st	Separation time per frame	μs
tt	Transfer time	μs

3.3.12 CPF 17 symbols

Symbol	Definition	Unit
APDUsize	Size of the application protocol data unit in octets	octets
BW_{NRTE}	Non-RTE bandwidth, in %	%
LDR	Link data rate in bit per seconds	bps
LTC	Total cable length in meter	m
M	Number packets in the port transmit queue of node i in front on of this packet	–
N	Number of nodes between sending and receiving end-stations	–
NF_{E/S_MAX}	Maximum number of frames allowed to be sent per second for one end station	pps

Symbol	Definition	Unit
$NF_{RTE/S}$	Number of frames allowed to be sent per second for one RTE end station	pps
Posize	Size of the protocol overhead in octets	octets
T_{CPD}	Cable propagation delay time in microseconds	µs
$T_{CPD/M}$	cable propagation delay in nanoseconds per meter (depending on the characteristics of the selected cable)	ns/m
T_{DELAY}	Delivery time in microseconds	µs
T_{DELAY_MAX}	Maximum delivery time in microseconds	µs
T_{DELAY_MIN}	Minimum delivery time in microseconds	µs
Throughput_RTE	Throughput RTE	octets/s
$Throughput\_RTE_{MAX}$	Maximum throughput RTE	octets/s
T_{NLD}	Node latency delay time in microseconds	µs
T_{NLD_i}	Node latency delay time of node i in microseconds	µs
T_{NPD}	Node propagation delay time in microseconds	µs
T_{NPD_i}	Node propagation delay time of node i in microseconds	µs
T_{PKT}	Packet transmit time in microseconds	µs
T_{PKT_i}	Packet transmit time of node i in microseconds	µs
T_{RCV}	Receiver stack traversal time including Phy and MAC in microseconds	µs
T_{SND}	Sender stack traversal time including Phy and MAC in microseconds	µs
$T_{TX\_PKT\_ij}$	packet transmit time of packet j in microseconds in the port transmit queue of node i in front on of this packet (depending on APDU size of node i)	µs
$T_{TX\_PKT\_j}$	packet transmit time of packet j in microseconds in the port transmit queue in front on of this packet (depending on APDU size of node i)	µs

3.3.13 CPF 18 symbols

Symbol	Definition	Unit
l_B	Distance along the cable in backward direction	m
l_C	Cable length	m
l_F	Distance along the cable in forward direction	m
NoDoB	Number of devices in backward direction	–
NoDoF	Number of devices in forward direction	–
NoS	Number of switching devices	–
t_{CD}	Cable delay	ns/m
t_{cyc}	Cycle time of communication system/relation	µs
t_D	Delivery time	µs
t_{data}	Transmit time of DLPDUs	µs
t_{pd}	Propagation delay	µs
t_{STsink}	Sink stack traversal time	µs
t_{STsrc}	Source stack traversal time	µs
t_{SW}	Delay time of a switch	µs

3.4 Conventions

3.4.1 Conventions common to all layers

3.4.1.1 (Sub)clause selection tables

(Sub)clause selection for all layers is defined in tables, as shown in Table 1 and Table 2. The selected base specifications are indicated just before the selection table(s). Selection is done at the highest (sub)clause level possible to define the profile selection unambiguously.

Table 1 – Layout of profile (sub)clause selection tables

Clause	Header	Presence	Constraints

Table 2 – Contents of (sub)clause selection tables

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

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

EXAMPLE concatenated subclauses

3.4 – 3.7	–	NO	–

3.4.1.2 Service selection tables

If the selection of services is defined in a table, the format of Table 3 is used. The table identifies the selected services and includes service constraints, as explained in Table 4.

Table 3 – Layout of service selection tables

Service ref.	Service name	Usage	Constraint

Table 4 – Contents of service selection tables

Column	Text	Meaning
Service ref.	<#>	(Sub)clause number of the base specifications where the service is defined
	–	Not applicable
Service name	<text>	The name of the service
Usage	M	Mandatory
	O	Optional
	–	Service is never used
Constraints	See <#>	Constraints/remarks are defined in the given subclause, table or figure of this profile document
	–	No constraints other than those given in the reference document (sub)clause, or not applicable
	<text>	The text defines the constraint directly; for longer text table footnotes or table notes may be used

If selection of service parameters is defined in a table the format of Table 5 is used. Each table identifies the selected parameters and includes parameter constraints, as explained in Table 6.

Table 5 – Layout of parameter selection tables

Parameter ref.	Parameter name	Usage	Constraint

Table 6 – Contents of parameter selection tables

Column	Text	Meaning
Parameter ref.	<#>	(sub)clause number of the base specifications where the service is defined
	–	Not applicable
Parameter name	<text>	The name of the service parameter
Usage	M	Mandatory
	O	Optional
	–	Attribute is never present
Constraints	See <#>	Constraints/remarks are defined in the given subclause, table or figure of this profile document
	–	No constraints other than those given in the reference document (sub)clause, or not applicable
	<text>	The text defines the constraint directly; for longer text table footnotes or table notes may be used

3.4.2 Physical layer

No additional conventions are defined.

3.4.3 Data-link layer

3.4.3.1 Service profile conventions

No additional conventions are defined.

3.4.3.2 Service and parameter selections

These are described using the common conventions, see 3.4.1.2.

3.4.4 Application layer

3.4.4.1 Service profile conventions

ASE and class selection is described using (sub)clause selection tables, see 3.4.1.1. If the use of selected ASE and classes is further constrained this is specified in the profile (e.g. an optional item of the base standard is mandatory in the profile).

If the selection of class attributes is defined in a table the format of Table 7 is used. The table identifies the selected class attributes and includes their constraints, as explained in Table 8.

Table 7 – Layout of class attribute selection tables

Attribute	Attribute Name	Usage	Constraint

Table 8 – Contents of class attribute selection tables

Column	Text	Meaning
Attribute	<#>	Attribute number of the base specification class
	–	Not applicable
Attribute Name	<text>	The name of the attribute
Usage	M	Mandatory
	O	Optional
	–	Attribute is never present
Constraints	See <#>	Constraints/remarks are defined in the given subclause, table or figure of this profile document
	–	No constraints other than those given in the reference document (sub)clause, or not applicable
	<text>	The text defines the constraint directly; for longer text table footnotes or table notes may be used

3.4.4.2 Service and parameter selections

These are described using the common conventions, see 3.4.1.2.

4 Conformance to communication profiles

A statement of compliance with an RTE Communication Profile Family (CPF) Profile of this part of IEC 61784 shall be stated[2] as either

– Compliance to IEC 61784-2:2014 CPF n <Type>, or
– Compliance to IEC 61784-2 (Ed.3.0) CPF n <Type>

and a statement of compliance with a communication profile (CP) of this part of IEC 61784 shall be stated as either

[2] In accordance with ISO/IEC Directives

– Compliance to IEC 61784-2:2014 CP n/n <Type>, or
– Compliance to IEC 61784-2 (Ed.3.0) CP n/n <Type>

where the Type within the angle brackets < > is optional and the angle brackets are not to be included. Type could be any character string.

A conformance statement should be supported with appropriate documentation as defined in Clause 6.

5 RTE performance indicators

5.1 Basic principles of performance indicators

A network that includes real-time communication and is based on the ISO/IEC 8802-3 standard is called a Real-time Ethernet (RTE) network. Users of RTE networks have different requirements for different applications. In order to satisfy these requirements in an optimal way RTE communication networks complying with CPs described in this standard will exhibit different performance.

Performance indicators (specified in 5.3) shall be used to specify capabilities of an RTE end device and an RTE communication network as well as to specify requirements of an application. Performance indicators will be used as a set of interaction means between the user of the RTE CP and the manufacturer of RTE CP compliant RTE end devices and network components. Subclause 5.2 specifies the application requirements view.

Performance indicators represent

a) capabilities of an RTE end device,
b) capabilities of an RTE communication network,
c) as well as requirements of an application.

A consistent set of performance indicators (specified in 5.3) is used to represent the RTE capabilities. Some of the performance indicators are interdependent; in this case some indicator values depend on the value of others to provide a consistent set.

NOTE The interdependence is due to physical or logical constraints, which are not changeable. For example it is not possible to have the indicators "Throughput RTE (which would use 90 % of the total bandwidth)" and "Throughput non-RTE (90 %)" at the same time because that would describe a transmission load of 180 %.

No general boundary values to specify RTE performance are specified for the indicators in this standard, but device suppliers need to specify boundary values for a CP-based product if they claim to be compliant to this standard.

Technology specific CPF subclauses specify

a) selection of performance indicators out of possible performance indicators defined in 5.3 relevant to a given CP, optionally with their individual limits or ranges,
b) interdependence between performance indicators,
c) optionally, lists with consistent performance indicators values.
   Each of the lists has one or more leading performance indicators. The leading performance indicators are preset to a fixed value (typically optimized to have the best overall performance). The other performance indicators in the list are shown with their related consistency limits,
d) optionally, a more comprehensive representation of the relation between performance indicators (Figure 1 shows an example of a graphical representation).

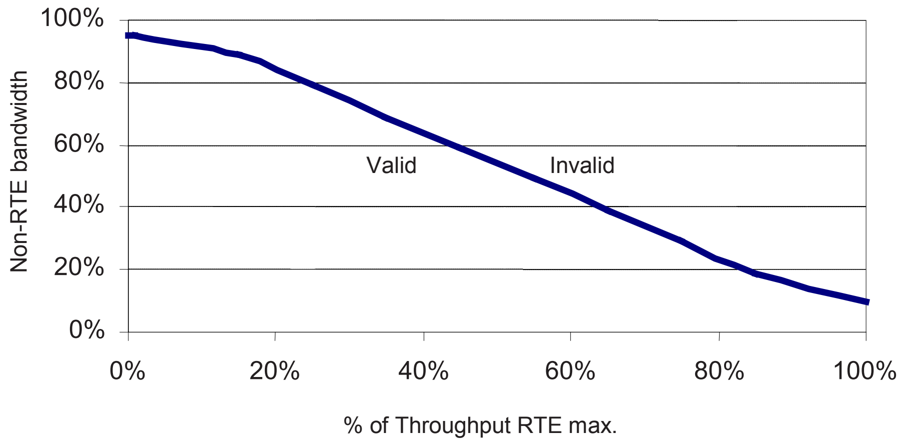

Figure 1 – Example of graphical representation of consistent indicators

The supplier of RTE end devices and RTE communication networks shall provide at least one consistent set of performance indicators. The boundary values given by the supplier should be based on conformance test principles specified in Clause 6.

NOTE 1 A set of lists with consistent performance indicators is only given when interdependence between performance indicators exists.

NOTE 2 It is possible that applications have requirements where one particular indicator has higher importance than all the others. Such applications will find useful the opportunity to select the consistent indicator list with the relevant leading indicator. Other applications may have requirements where several indicators are of equally high importance. For such applications, a graphical or otherwise more comprehensive representation of the relation between consistent indicators is more appropriate. Figure 1 is an example of a graphical representation of consistent indicators given by a CP.

NOTE 3 RTE end devices are designed under the discretion of manufactures of such a device. Therefore no assumption could be made how many RTE end-stations (network interfaces) are build in one device. In order to achieve comparable performance indicators from the application perspective the performance indicators are build on RTE end-stations not on RTE devices.

5.2 Application requirements

The capabilities of an RTE communication network are specified in 5.3 as indicators. The indicators are used to match application requirements to the capabilities of components compliant to one or more CP(s) of this part of IEC 61784.

A profile is suitable if its indicator values at least meet the required indicator values.

NOTE 1 Sophisticated requirements are likely to find a smaller number of matching profiles.

NOTE 2 A principle for selecting the matching CP is described in ISO 15745-1.

The application-dependent class should be a subset of a CP x/y to be suitable for this application.

5.3 Performance indicators

5.3.1 Delivery time

Delivery time shall indicate the time needed to convey an APDU containing data (message payload) that has to be delivered in real-time from one node (source) to another node (destination). The delivery time is measured at the interface between the application process and the (Fieldbus) application entity.

NOTE 1 A description of the Application Layer concept with a description of the Application Process and the Application Entity is given in the respective type-specific part of IEC 61158-5.

The maximum delivery time shall be stated for the following two cases:

- no transmission errors, and
- one lost frame with recovery.

NOTE 2 The permanent failure condition is described in 5.3.9.

Calculation of the maximum delivery time shall include the transmission time as well as any waiting time.

NOTE 3 Waiting time depends on the RTE network concept, the RTE network topology and the application load which is generated by the other nodes in the RTE network and the non-RTE traffic at that time.

5.3.2 Number of RTE end-stations

The number of RTE end-stations shall state the maximum number of RTE end-stations supported by a CP.

NOTE The network devices like a switch are not counted in the number of RTE end-stations.

5.3.3 Basic network topology

The basic network topology supported by a CP shall be stated out of the topologies listed in Table 9 or as a combination.

Table 9 – Basic network topology types

Basic network topology	CP
Hierarchical star	CP m/1
Ring (loop)	CP m/2
Linear topology	CP m/3
NOTE A real topology could be any combination of the three basic topologies.	

5.3.4 Number of switches between RTE end-stations

Number of switches between any two RTE end-stations that have an application relation.

5.3.5 Throughput RTE

Throughput RTE shall indicate the total amount of APDU data (by octet length) on one link per second.

5.3.6 Non-RTE bandwidth

The non-RTE bandwidth shall indicate the percentage of bandwidth, which can be used for non-RTE communication on one link. Additionally the total link bandwidth shall be specified.

NOTE The indicators throughput RTE and non-RTE bandwidth are related to each other.

5.3.7 Time synchronization accuracy

Time synchronization accuracy shall indicate the maximum deviation between any two node clocks.

5.3.8 Non-time-based synchronization accuracy

The non-time-based synchronization accuracy shall indicate the maximum jitter of the cyclic behavior of any two nodes, using triggering by periodical events over the network for establishing cyclic behavior.

NOTE 1 This factor accounts for coherency of data or actions triggered by the event, and it is a measure of the coherency spread.

NOTE 2 The event can be unicast, multicast or broadcast, or made of a set of simpler events.

5.3.9 Redundancy recovery time

Redundancy recovery time shall indicate the maximum time from failure to become fully operational again in case of a single permanent failure.

NOTE If a permanent failure occurs, the delivery time of a message is the redundancy recovery time.

6 Conformance tests

6.1 Concept

This part of IEC 61784 specifies the methodology of a conformance test for an RTE end device for one or more CPs. The concept of this conformance test is to verify the capabilities of a device under test (DUT) against a consistent set of indicators of a CP. The conformance test shall assure the interoperability of devices which claim compliance with the same CP. Figure 2 gives an overview of the conformance test related to this part of IEC 61784.

NOTE Conformance test implementation and conformance test execution are not defined in this standard.

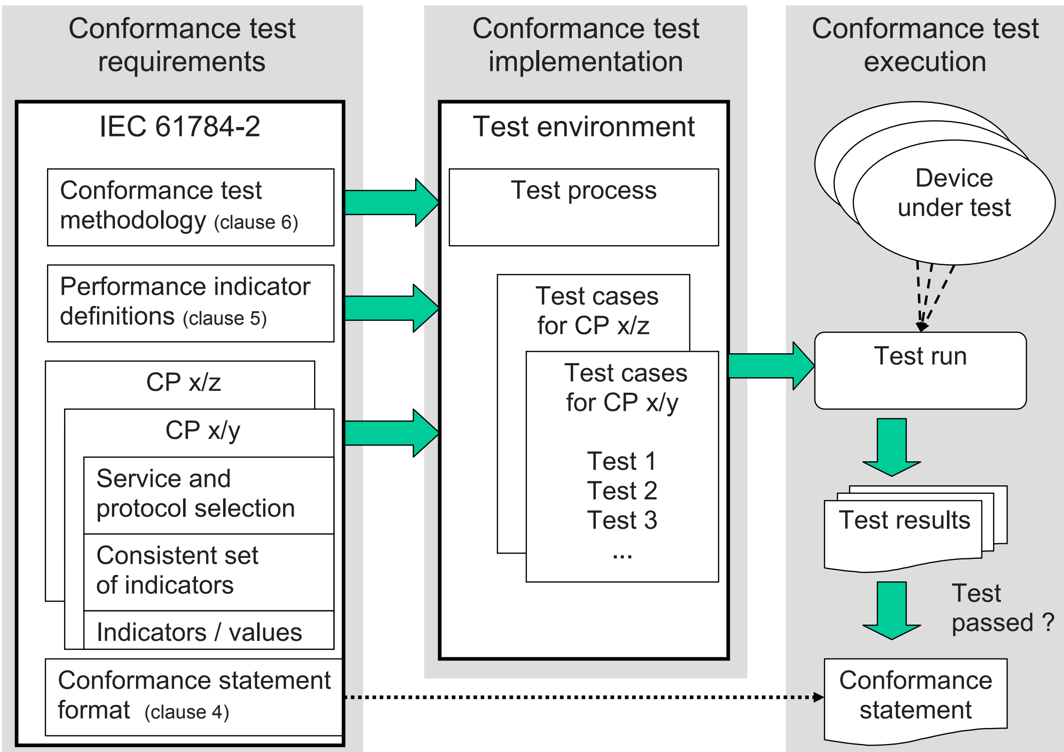

Figure 2 – Conformance test overview

6.2 Methodology

Test cases shall be developed in a way that tests are repeatable and the results can be verified. Test results shall be documented and shall be used as the basis for the conformance statement.

Conformance tests of a device shall include, as appropriate, the verification of

- the availability and correctness of the specified CP functionality,
- network related indicator values,
- device related indicator values.

The performance indicator values of the CP and of the device under test shall be used.

NOTE 1 It is assumed that the quality of the test cases guarantees the interoperability of a tested device. If any irregularities are reported the test cases will be adapted accordingly.

NOTE 2 A description of a conformance testing process is given in ISO/IEC 9646 series.

6.3 Test conditions and test cases

Test conditions and test cases shall be defined and documented based on a specific CP. This shall include the following indicators, when applicable:

- number of nodes;
- network topology;
- number of switches between nodes;
- RTE throughput,
- non-RTE bandwidth.

For each measured indicator (see 6.4), test condition and test case documents shall be prepared and shall describe:

- test purpose;
- test setup;
- test procedure;
- criteria for compliance.

Test set-up describes the equipment set-up necessary to perform the test including measurement equipment, device under test, auxiliary equipment, interconnection diagram, and test environmental conditions.

Parts of the test environment may be emulated or simulated. The effects of the emulation or simulation shall be documented.

The test procedure describes how the test should be performed, which also includes a description of specific set of indicators required to perform this test. The criteria for compliance define test results accepted as compliance with this test.

6.4 Test procedure and measuring

The measured indicators shall include, when applicable:

- delivery time;
- RTE throughput;
- non-RTE bandwidth;

- time synchronization accuracy;
- non-time based accuracy;
- redundancy recovery time.

The test procedure shall be based on the principles of 6.3.

The sequence of measuring actions to complete a test run shall be provided.

The number of independent runs of the test shall be provided.

The method to compute the result of the test from the independent runs shall be provided if applicable.

6.5 Test report

The test report shall contain sufficient information so that the test can be repeated and the results verified.

The test report shall contain at least

- the reference to the conformance test methodology according to 6.2,
- the reference to the performance indicator definitions according to Clause 5,
- the reference to the used CP according to this part of IEC 61784,
- a description of the conformance test environment including network emulators, measurement equipment and the person or organization responsible for the test execution, and the date of testing,
- the device under test, its manufacturer, and hardware and software revision,
- the number and type of devices connected to the network together with the topology,
- a reference to the test case specifications,
- the measured values,
- a statement according compliance with the CP.

7 Communication Profile Family 2 (CIP™[3]) – RTE communication profiles

7.1 General overview

Communication Profile Family 2 defines several communication profiles based on IEC 61158-2 (protocol type 2), IEC 61158-3-2, IEC 61158-4-2, IEC 61158-5-2, and IEC 61158-6-2, and on other standards. These profiles all share for their upper layers the same communication system commonly known as the Common Industrial Protocol (CIP).

This part of IEC 61784 defines two RTE communication profiles.

– Profile 2/2 EtherNet/IP™[4]

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[3] CIP™ is a trade name of ODVA, Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name CIP™. Use of the trade name CIP™ requires permission from ODVA, Inc.

[4] EtherNet/IP™ is a trade name of ODVA, Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name EtherNet/IP™. Use of the trade name EtherNet/IP™ requires permission from ODVA, Inc.

This profile contains a selection of AL, DLL and PhL services and protocol definitions from IEC 61158-4-2, IEC 61158-5-2, and IEC 61158-6-2, and the TCP/UDP/IP/Ethernet protocol suite. This profile uses the CIP protocol and services in conjunction with the standard internet and Ethernet standards. This profile provides ISO/IEC 8802-3 and IEEE 802.3-2008 based real time communication, through the use of frame prioritization.

– Profile 2/2.1 EtherNet/IP™ with time synchronization

This profile is an extension of CP 2/2 that defines additional mechanisms to provide accurate time synchronization between nodes using EtherNet/IP. The addition of time synchronization services and protocols based on IEC 61588:2009 allows using it also for the most demanding applications.

NOTE 1 See IEC 61784-1, Clause A.2, for an overview of CIP and related networks communications concepts.

NOTE 2 Additional CPs are defined in the other parts of the IEC 61784 series.

7.2 Profile 2/2

7.2.1 Physical layer

See IEC 61784-1, 6.3.1.

7.2.2 Data-link layer

See IEC 61784-1, 6.3.2.

7.2.3 Application layer

See IEC 61784-1, 6.3.3.

7.2.4 Performance indicator selection

7.2.4.1 Performance indicator overview

Table 10 provides an overview of CP 2/2 performance indicators.

Table 10 – CP 2/2: PI overview

Performance indicator	Applicable	Constraints
Delivery time	Yes	None
Number of end-stations	Yes	None
Basic network topology	Yes	Only star topology is supported
Number of switches between end-stations	Yes	None
Throughput RTE	Yes	None
Non-RTE bandwidth	Yes	None
Time synchronization accuracy	No	–
Non-time-based synchronization accuracy	No	–
Redundancy recovery time	No	–

7.2.4.2 Performance indicator dependencies

7.2.4.2.1 Dependency matrix

Table 11 shows the dependencies between performance indicators for CP 2/2.

Table 11 – CP 2/2: PI dependency matrix

Dependent PI	Influencing PI					
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth
Delivery time		No	No	Yes	No	No
Number of end-stations	No		Yes	Yes	No	No
Basic network topology	No	No		No	No	No
Number of switches between end-stations	Yes	Yes	Yes		No	No
Throughput RTE	No	No	No	No		Yes
Non-RTE bandwidth	No	No	No	No	Yes	

7.2.4.2.2 Delivery time

Payload delivery time between any two end-stations depends on many factors as shown below. For one direction of a CP 2/2 network operating in full-duplex mode it can be calculated for each type of application message using Formulae (1), (2) and (3).

$$DT = SD_s + T_{x\_packet} + \sum_{i=1}^{n-1} CD_i + \sum_{k=1}^{n} SL_k + SD_r \qquad (1)$$

$$CD_i = PD_i \times CL_i \qquad (2)$$

$$SL_k = SPD_k + \sum_{j=1}^{q} T_{x\_packet\_j} + T_{x\_packet} \qquad (3)$$

where

DT	is the delivery time in microseconds;
SD_s	is the sender stack delay in microseconds (depending on the selected hardware platform and the embedded software implementation);
T_{x_packet}	is the packet transmit time in microseconds;
N	is the number of switches between sending and receiving end-stations;
CD	is the cable segment delay in microseconds;
PD	is the cable propagation delay in nanoseconds per meter (depending on the characteristics of the selected cable);
CL	is the cable segment length in meters;
SL	is the switch latency in microseconds (measured based on RFC 2544, usually provided by the switch vendor);
SPD	is the switch processing delay in microseconds (provided by the switch vendor instead of SL);
Q	is the number packets in the port transmit queue in front on of this packet;
$T_{x\_packet\_j}$	is the transmit time of packet j;
SD_r	is the receiver stack delay in microseconds (depending on the selected hardware platform the and embedded software implementation).

NOTE If a packet is lost, e.g. due to a transmission error, but the following one is received without errors then the delivery time will double. The CP 2/2 system performance will not be affected unless four consecutive packets are lost.

7.2.4.2.3 Number of end-stations

With regard to star topology, this standard considers network infrastructures containing only data-link layer (Ethernet) switches. This assumes that all end-stations are connected to the same subnet. Based on the CP 2/2 specification, a subnet can contain a maximum of 1 024 end-stations. The minimum number of end-stations is two, one producer and one consumer of the RTE data.

7.2.4.2.4 Basic network topology

The basic topology of the CP 2/2 network is a hierarchical star. Since basic network topology is given, it is not dependent on, or influenced by, any of the performance indicators.

7.2.4.2.5 Number of switches between end-stations

The number of switches between end-stations, which is the number of layers in a hierarchical star, is determined on the basis of:

– delivery time;
– number of end-stations, their physical location and the distance between them;
– network traffic profile (types of traffic, rates, traffic mix);
– performance of selected switches, in particular their throughput, their physical location, distance between them and number of ports per switch;
– network management requirements.

The minimum number is 1. The maximum number is 1 024 where each end-station has an individual switch, which is similar to the linear topology.

7.2.4.2.6 Throughput RTE

In switched Ethernet networks based on the star topology a link is a link between an end-station and a switch port. Based on the definition provided in 5.3.5, throughput RTE depends on the link data rate, link mode of operation (half or full-duplex) and protocol overhead. Throughput RTE for one direction of a CP 2/2 link operating in a full-duplex mode can be calculated on the basis of Formula (4).

$$Throughput\_RTE = \sum_{i=1}^{k} (APDUsize_i \times EN\_RTE\_PR_i) \leq EN\_PR\_MAX \quad (4)$$

where

APDUsize	is the size of the application protocol data unit per CP 2/2 connection in octets;
EN_RTE_PR	is the end-station RTE packet rate per CP 2/2 connection in packets per second (pps);
k	is the number of CP 2/2 connections supported by the end-station;
EN_PR_MAX	is the end-station maximum packet rate in pps.

7.2.4.2.7 Non-RTE bandwidth

CP 2/2 does not specify a percentage of bandwidth which can be used for non-RTE communication but it can be calculated as shown below.

7.2.4.2.8 Relation between throughput RTE and non-RTE bandwidth

A link in the CP 2/2 is a link between an end-station and a switch port. The total link bandwidth is limited by the end-station throughput, which is the same as the end-station maximum packet rate. The total link bandwidth is therefore a sum of end-station RTE and non-RTE packet rates and can be calculated using Formulae (5), (6), (7), (8) and (9).

$$Total\_Link\_Bandwidth = EN\_PR\_MAX \quad (5)$$

$$EN\_PR = EN\_TRTE\_PR + EN\_TNRTE\_PR \le EN\_PR\_MAX \quad (6)$$

$$EN\_TRTE\_PR = \sum_{i=1}^{p} EN\_RTE\_PR_i \quad (7)$$

$$EN\_TNRTE\_PR = \sum_{j=1}^{m} EN\_NRTE\_PR_j \quad (8)$$

$$NRTE\_BW = \frac{EN\_PR\_MAX - EN\_TRTE\_PR}{EN\_PR\_MAX} \times 100\% \quad (9)$$

where

EN_PR	is the end-station packet rate in packets per second (pps);
EN_PR_MAX	is the end-station maximum packet rate in pps;
EN_TRTE_PR	is the end-station total RTE packet rate in pps;
EN_RTE_PR	is the end-station RTE packet rate per CP 2/2 connection in pps;
p	is the number of CR 2/2 RTE connections;
EN_TNRTE_PR	is the end-station total non-RTE packet rate in pps;
EN_NRTE_PR	is the end-station non-RTE packet rate per CP 2/2 connection in pps;
m	is the number of CR 2/2 non-RTE connections;
NRTE_BW	is the non-RTE bandwidth, in %.

EXAMPLE

End device maximum packet rate is 2 000 pps. It has 5 RTE connections, 2 with EN_RTE_PR = 200 pps and 3 with EN_RTE_PR = 100 pps. It also has 4 non-RTE connections, all with EN_NRTE_PR = 10 pps.

$$EN\_TRTE\_PR = 2 \times 200\,pps + 3 \times 100\,pps = 700\,pps$$

$$EN\_PR = 700\,pps + 40\,pps = 740\,pps$$

$$NRTE\_BW = \frac{40\,pps}{2000\,pps} \times 100\% = 2\%$$

$$NRTE\_BW_{max} = \frac{2000\,pps - 700\,pps}{2000\,pps} \times 100\% = 65\%$$

In this example 65 % of link bandwidth can be used for non-RTE traffic but only 2 % has actually been used.

7.2.4.3 Consistent set of performance indicators

Table 12 defines a consistent set of performance indicators for CP 2/2. Minimum and maximum values of delivery time are calculated in A.1.1.1. The maximum value of the throughput RTE is calculated in A.1.1.2.

Table 12 – CP 2/2: Consistent set of PIs for factory automation

Performance indicator	Value	Constraints
Delivery time	130 µs to 20,4 ms	–
Number of end-stations	2 to 1 024	–
Number of switches between end-stations	1 to 1 024	–
Throughput RTE	0 octets/s to 3,44 x 10^6 octets/s	–
Non-RTE bandwidth	0 % to 100 %	–

7.3 Profile 2/2.1

7.3.1 Physical layer

The physical layer of the Ethernet/IP CP 2/2.1 profile is according to ISO/IEC 8802-3 and IEEE 802.3-2008.

Recommended connectors and cables are specified in IEC 61918 and IEC 61784-5-2.

NOTE 1 EtherNet/IP can be used with a number of media options (e.g. copper, fiber, fiber ring, wireless) in conjunction with the Ethernet lower layers.

NOTE 2 Additional information is provided in ODVA: THE CIP NETWORKS LIBRARY – Volume 2: EtherNet/IP™ Adaptation of CIP, Chapter 8: Physical Layer.

The time stamping feature for time synchronization is implemented using a hardware assist circuit as specified in IEC 61588:2009.

7.3.2 Data-link layer

7.3.2.1 DLL service selection

The data-link layer of the CP 2/2.1 profile is according to ISO/IEC 8802-3 and IEEE 802.3-2008.

7.3.2.2 DLL protocol selection

The data-link layer of the CP 2/2.1 profile is according to ISO/IEC 8802-3 and IEEE 802.3-2008.

Table 13 specifies the DLL protocol selection within IEC 61158-4-2.

Table 13 – CP 2/2.1: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviations and conventions	YES	–
4 – 5	–	NO	–
6	Specific DLPDU structure, encoding and procedures	–	–
6.1	Modeling language	YES	–
6.2 – 6.15	–	NO	–
7	Objects for station management	–	See Table 14
8 – 9	–	NO	–
10	Device Level Ring (DLR) protocol	YES	Optional
Annex A	(normative) – Indicators and switches	–	–
A.1	Purpose	YES	–
A.2	Indicators	–	–
A.2.1	General indicator requirements	YES	–
A.2.2	Common indicator requirements	YES	–
A.2.3	Fieldbus specific indicator requirements (1)	NO	–
A.2.4	Fieldbus specific indicator requirements (2)	YES	–
A.2.5	Fieldbus specific indicator requirements (3)	NO	–
A.3	Switches	–	–
A.3.1	Common switch requirements	YES	–
A.3.2	Fieldbus specific switch requirements (1)	NO	–
A.3.3	Fieldbus specific switch requirements (2)	YES	–
A.3.4	Fieldbus specific switch requirements (3)	NO	–

Table 14 specifies the management objects selection.

Table 14 – CP 2/2.1: DLL protocol selection of management objects

Clause	Header	Presence	Constraints
7	Objects for station management	–	–
7.1	General	Partial	Relevant objects and features only
7.2	ControlNet object	NO	–
7.3	Keeper object	NO	–
7.4	Scheduling object	NO	–
7.5	TCP/IP interface object	YES	–
7.6	Ethernet link object	YES	–
7.7	DeviceNet object	NO	–
7.8	Connection configuration object	YES	–
7.9	DLR object	YES	Optional (required if DLR protocol is implemented)
7.10	QoS object	YES	Optional
7.11	Port object	YES	–

7.3.3 Application layer

7.3.3.1 AL service selection

Table 15 specifies the AL service selection within IEC 61158-5-2.

Table 15 – CP 2/2.1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviations and conventions	YES	–
4	Common concepts	Partial	Differences are indicated in IEC 61158-5-2, 6.1
5	Data type ASE	Partial	Selection and restrictions are specified in IEC 61158-5-2, 6.1
6	Communication model specification	–	–
6.1	Concepts	YES	–
6.2	ASEs	–	–
6.2.1	Object management ASE	–	–
6.2.1.1	Overview	YES	–
6.2.1.2	FAL management model class specification	–	–
6.2.1.2.1	General formal model	YES	–
6.2.1.2.2	Identity formal model	YES	–
6.2.1.2.3	Assembly formal model	YES	–
6.2.1.2.4	Message router formal model	YES	–
6.2.1.2.5	Acknowledge handler formal model	YES	–
6.2.1.2.6	Time Sync formal model	YES	–
6.2.1.2.7	Parameter formal model	YES	–
6.2.1.3	FAL management model ASE service specification	YES	–
6.2.2	Connection manager ASE	YES	Single class in this ASE
6.2.3	Connection ASE	YES	Optional (internal or external)
6.3	AR's	–	–
6.3.1	Overview	YES	–
6.3.2	UCMM AR formal model	NO	–
6.3.3	Transport AR formal model	YES	–
6.3.4	AR ASE services	YES	–
6.4	Summary of FAL classes	YES	–
6.5	Permitted FAL services by AR type	YES	–

In addition AL services are mapped onto the TCP/UDP/IP protocol suite.

The corresponding minimum requirements for EtherNet/IP devices are as specified in RFC 1122, RFC 1123, RFC 1127 and subsequent documents that may supersede them. All EtherNet/IP devices shall as a minimum support requirements specified in RFC 768, RFC 791, RFC 792, RFC 793, RFC 826, RFC 894, RFC 1112 and RFC 2236.

If a feature or internet protocol is implemented by an EtherNet/IP device, this feature shall be implemented in accordance with the appropriate RFC documents, whether the feature or protocol is considered required or optional by this RFC document.

7.3.3.2 AL protocol selection

Table 16 specifies the AL protocol selection within IEC 61158-6-2.

Table 16 – CP 2/2.1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviations and conventions	YES	–
4	Abstract syntax	–	–
4.1	FAL PDU abstract syntax	–	–
4.1.1 – 4.1.2	–	YES	–
4.1.3	UCMM_PDUs	NO	–
4.1.4	Transport_Headers	YES	–
4.1.5	CM_PDUs	Partial	Except 4.1.5.6.6
4.1.6 – 4.1.11	–	YES	–
4.2	Data abstract syntax specification	YES	–
4.3	Encapsulation abstract syntax	YES	–
5	Transfer syntax	YES	–
6	Structure of FAL protocol state machines	YES	–
7	AP-Context state machine	YES	–
8	FAL service protocol machine (FSPM)	YES	–
9	Application relationship protocol machines (ARPMs)	–	–
9.1	General	YES	–
9.2	Connection-less ARPM (UCMM)	–	–
9.2.1	General	YES	–
9.2.2 – 9.2.6	–	NO	–
9.3	Connection-oriented ARPMs (transports)	YES	–
10	DLL mapping protocol machine 1 (DMPM 1)	NO	–
11	DLL mapping protocol machine 2 (DMPM 2)	YES	–
12	DLL mapping protocol machine 3 (DMPM 3)	NO	–

In addition, the AL protocol is mapped onto the TCP/UDP/IP protocol suite.

The corresponding minimum requirements for EtherNet/IP devices are as specified in RFC 1122, RFC 1123, RFC 1127 and subsequent documents that may supersede them. All EtherNet/IP devices shall as a minimum support requirements specified in RFC 768, RFC 791, RFC 792, RFC 793, RFC 826, RFC 894, RFC 1112 and RFC 2236.

If a feature or internet protocol is implemented by an EtherNet/IP device, this feature shall be implemented in accordance with the appropriate RFC documents, whether the feature or protocol is considered required or optional by this RFC document.

The time synchronization protocol is implemented as specified in IEC 61588:2009.

7.3.4 Performance indicator selection

7.3.4.1 Performance indicator overview

Table 17 provides an overview of CP 2/2.1 performance indicators.

Table 17 – CP 2/2.1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	Yes	None
Number of end-stations	Yes	None
Basic network topology	Yes	Only star topology is detailed in this standard
Number of switches between end-stations	Yes	None
Throughput RTE	Yes	None
Non-RTE bandwidth	Yes	None
Time synchronization accuracy	Yes	Requires switches capable to function as IEC 61588:2009 transparent clocks or boundary clocks, depending on application.
Non-time-based synchronization accuracy	No	–
Redundancy recovery time	No	–

7.3.4.2 Performance indicator dependencies

7.3.4.2.1 Dependency matrix

Table 18 shows the dependencies between performance indicators for CP 2/2.1.

Table 18 – CP 2/2.1: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time sync accuracy
Delivery time		No	No	Yes	No	No	No
Number of end-stations	No		Yes	Yes	No	No	Yes
Basic network topology	No	No		No	No	No	No
Number of switches between end-stations	Yes	Yes	Yes		No	No	Yes
Throughput RTE	No	No	No	No		Yes	No
Non-RTE bandwidth	No	No	No	No	Yes		No
Time synchronization accuracy	No	No	Yes	Yes	No	No	

7.3.4.2.2 Time synchronization accuracy

Accuracy of time synchronization is the maximum jitter between master and slave clocks. In order to achieve 1 μs accuracy in a star network, it is necessary to use switches containing

IEC 61588:2009 boundary clocks. It has been proven that in this case the number of cascaded switches shall not exceed four (4), assuming that the accuracy of the switch boundary clock is within the range of ± 100 ns.

7.3.4.3 Consistent set of performance indicators

Table 19 defines a consistent set of performance indicators for CP 2/2.1. Minimum and maximum values of delivery time are calculated in A.1.2.1. The maximum of nodes is calculated in A.1.2.2. The maximum value of the throughput RTE is calculated in A.1.1.2.

Table 19 – CP 2/2.1: Consistent set of PIs for motion control

Performance indicator	Value	Constraints
Delivery time	130 µs to 190 µs	–
Number of end-stations	2 to 90	Maximum number of ports in switches with IEC 61588:2009 support
Number of switches between end-stations	1 to 4	Maximum number of cascaded switches with IEC 61588:2009 support
Throughput RTE	0 octets/s to 3,44 x 10^6 octets/s	–
Non-RTE bandwidth	0 % to 100 %	–
Time synchronization accuracy	≤ 1 µs	–

8 Communication Profile Family 3 (PROFIBUS & PROFINET[5]) – RTE communication profiles

8.1 General overview

8.1.1 CPF 3 overview

Communication Profile Family 3 (CPF 3) defines communication profiles using Type 3 and Type 10 of IEC 61158 series, which corresponds to parts of the communication systems commonly known as PROFIBUS and PROFINET. For PROFIBUS CP 3/1 and CP 3/2 are specified in IEC 61784-1.

RTE specific PROFINET profiles are specified for three conformance classes named A, B, and C. Compliance to a CP out of the CPF 3 is a prerequisite to conform to a conformance class (see Table 55). Those conformance classes require features out of the general classifications given in 8.1.3, 8.1.4, 8.1.5, 8.1.6, 8.1.7, 8.1.8, 8.1.9, 8.1.10, and 8.1.11.

8.1.2 Administrative numbers

The administrative numbers shown in IEC 61158–6–10, shall be assigned by the authority shown in Table 20.

5 PROFIBUS and PROFINET are trade names of the non-profit organization PROFIBUS Nutzerorganisation e.V. (PNO). This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trade names holder or any of its products. Compliance to this profile does not require use of the registered trade name. Use of the trade names requires permission of the trade name holder.

Table 20 – Administrative numbers assignment

Parameter	Assigning authority
application process identifier	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, 3.2.9 See IEC 61158–6–10, Coding of the field API
vendor ID	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, 3.2.90 See IEC 61158–6–10, Coding of fields related to Instance, DeviceID, VendorID
enterprise number	IANA to PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, 6.3.16.2.2 See IEC 61158–6–10, Enterprise number for PNIO MIB
PNIO MIB	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, 6.3.16.2.2 See IEC 61158–6–10, Enterprise number for PNIO MIB
API	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, 7.1.6 See IEC 61158–6–10, Coding of the field API
index	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, 3.2.54 See IEC 61158–6–10:2013, Coding of the field Index
IM_Profile_ID	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, 7.3.6.3.19 (See Profile ID) See IEC 61158–6–10, Coding of the field IM_Profile_ID
ChannelErrorType	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, 7.3.4.2.2 See IEC 61158–6–10, Coding of the field ChannelErrorType

8.1.3 Node Classes

8.1.3.1 General

Node classes are:

- IO device, with or without an integrated network component;
- IO controller, with or without an integrated network component;
- IO supervisor, and
- Network components (e.g. switch, wireless access point, wireless client).

A node may have several node classes implemented at the same time, e.g. IO controller and IO device, IO device and integrated network component.

8.1.3.2 IO device

An IO device shall support at least one AR with two IO CRs, one Alarm CR, and one Record Data CR with the following features:

- IO CR:
  Maximum C_SDU data length 1 440 octets

Minimum C_SDU data length 40 octets
Usable C_SDU data length according to the general station description (GSD)

NOTE 1 C_SDU is derived from the IEC 61158–6–10.

- Alarm CR:
  Up to 1 432 octet data length, minimal 200 octets data length
- Record data CR:
  Up to 2^{32} – 65 octet data length, minimal 4 132 octets data length (length of the *PROFINETIOServiceReqPDU or PROFINETIOServiceResPDU*)

NOTE 2 *PROFINETIOServiceReqPDU* and *PROFINETIOServiceResPDU* are derived from IEC 61158–6–10.

8.1.3.3 IO controller

An IO controller shall support at least one AR for each related IO device including two IO CRs, one Alarm CR, and one Record Data CR with the following features:

- IO CR:
  Up to 1 440 octets C_SDU data length, min. 240 octets consistency, support of all defined data types
- Alarm CR:
  Up to 1 432 octets data length, minimal 200 octets data length, capability to queue at least one high prior and one low prior alarm for each related IO device
- Record data CR:
  Up to 2^{32}-65 octets data length, minimal 4 132 octets data length (length of the *PROFINETIOServiceReqPDU or PROFINETIOServiceResPDU*), capability to store for each related IO device 16 Koctets startup parameter, no parallel access to a record data object
- Multi-API:
  At least two supported (API = 0 and API = x)
- Connect response:
  At least an ARVendorBlockRes size of 512 octets for each used ARVendorBlockReq at the connect request

NOTE ARVendorBlockReq and ARVendorBlockRes are derived from the IEC 61158–6–10.

8.1.4 Timing parameters

8.1.4.1 Internet protocol and Dynamic name service

The recommended values for the IP layer defined in IETF RFC 791 are shown in Table 21 and Table 22.

Table 21 – IP layer parameters for IO controller

Parameter	Value	Comment
ARP_Cache_Size	Minimum 32	The amount of the supported IODs
ARP_Cache_Timeout	60 s	–

Table 22 – IP layer parameters for IO device

Parameter	Value	Comment
ARP_Cache_Size	Minimum 32	–
ARP_Cache_Timeout	60 s	–

The allowed time values for name resolution defined in IEC 61158–6–10, 4.12 are shown in Table 23.

Table 23 – Timeout values for name resolution

Parameter	Value	Comment
ARP-ResponseTimeout	2 s	See RFC 826
DCP-IdentifyTimeout	≥ 400 ms	See IEC 61158–6–10, 4.3.2
DCP-Set/GetTimeout	1 s	See IEC 61158–6–10, 4.3.2
DCP MaxRetryLimit Set/Get	2	See IEC 61158–6–10, 4.3.2
DNS-RequestTimeout	16 s	See RFC 1034

8.1.4.2 IO device

Table 24 contains limitations for AL timing parameters of an IO device.

Table 24 – Reaction time for an IO device

Parameter	Meaning	Value
MinDeviceInterval [a]	This performance parameter is an IO device property and part of the device description.	≤ 128 ms for CP 3/4 and CP 3/5 ≤ 1 ms for CP 3/6
MinDeviceIntervalUDP	This performance parameter is an IO device property.	≤ 4 000 ms for RT_CLASS_UDP
Remote_Application_Timeout [b]	The parameter Remote_Application_Timeout represents the deadline of a RPC call.	≤ 300 s
Remote_Application_Ready_Timeout [c]	The parameter Remote_Application_Ready_Timeout represents the deadline between IODControlRes (ControlCommand.PrmEnd) and IOXControlReq (ControlCommand.ApplicationReady).	≤ 300 s
Set_Storage_Time [c]	Maximum time between the DCP_Set.rsp and the completion of persistent storage.	≤ 30 s mandatory
Set_Usage_Time [c]	Maximum time between the DCP_Set.rsp and the usage of the set values in all affected protocols. For the IP suite see IP_Startup_Time.	≤ 400 ms mandatory
IP_Startup_Time [c]	Time between the DCP_Set.rsp and the accessibility of the IP layer with ARP [d] or the PROFINETIOServiceReqPDU.	≤ 30 s recommended ≤ 300 s mandatory
Reset_to_Factory_Time [c]	Time between the DCP_Set.rsp and the deletion of the name of station and the IP parameter.	≤ 30 s recommended ≤ 300 s mandatory

[a] See ISO 15745–4/Amendment 1
[b] See OSF C706
[c] See IEC 61158–6–10
[d] See IETF RFC 826

An IO device shall support ReductionRatio SendClockFactor combinations, which fulfill the Formula (10).

$$\text{MinDeviceInterval} \leq \text{SCF} \times \text{RR} \times 31{,}25\,\mu\text{s} \tag{10}$$

$$\text{RR} \geq \frac{\text{MinDeviceInterval}}{\text{SCF} \times 31{,}25\,\mu\text{s}}$$

where

MinDeviceInterval	is the archieved communication interval;
SCF	is the attribute *SendClockFactor* (see IEC 61158–5–10, Send Clock Factor);
RR	is the attribute *ReductionRatio* (see IEC 61158–5–10, Reduction Ratio);
31,25 µs	is the basic clock rate.

Each IO device implementation shall ensure that the MinDeviceInterval and Remote_Application_Timeout reach the smallest possible value.

The supported SCF in conjunction with the MinDeviceInterval limits the supported RR of a device.

8.1.4.3 Media redundancy protocol

The allowed time values for MRP defined in IEC 61158–6–10 are shown in Table 25.

Table 25 – Maximum time values for MRP

Parameter	Value	Comment
MaxBridgeDelay for MRP [a]	≤ 4 ms	Every bridge supporting MRP shall forward a MRP-PDU in this time.

[a] A lesser BridgeDelay allows a greater Number of Switches (NoS) in a ring topology. With the maximum value the Number of Switches (NoS) in a ring topology is reduced to NoS<15.

8.1.4.4 Precision transparent clock protocol

The allowed time values for PTCP defined in IEC 61158–6–10 are shown in Table 26.

Table 26 – Maximum time values for PTCP

Parameter	Value	Comment
Max Delay Request Repeat	5	–
Max Delay Response Time	< 10 ms	Recommended
Max Delay Response Time	< 25 ms	Mandatory
Max Bridge Delay	≤ 4 ms	Recommended
Max Bridge Delay	≤ 40 ms	Mandatory
Timestamp accuracy	≤ 10 ns	Recommended

8.1.4.5 Link layer discovery protocol

The allowed time values for LLDP defined in IEC 61158–6–10 and IEEE 802.1AB are shown in Table 27.

Table 27 – Maximum time values for LLDP

Parameter	Value	Comment
msgTxHold	4	Multiplier for msgTxInterval to calculate the txTTL.
msgTxInterval	5 s	Time between two consecutive LLDP frames without any content change during steady state operation.
txTTL	21 s	Time an information from a neighbor is stored.
txFast	TRUE	Immediate transmission of a LLDP frame is used, whenever a change of the content of the local LLDP data or of the neighborhood is detected.

8.1.5 Communication classes

8.1.5.1 General

All communication classes allow IEEE 802 series and IETF communications combined with the RTE specific additions. Communication classes are:

- RT Class 1 (content specified in attribute RT_CLASS_1, see IEC 61158–5–10, 6.3.4.2.2),
- RT Class 2 (legacy, content specified in attribute RT_CLASS_2, see IEC 61158–5–10, 6.3.4.2.2), and
- RT Class 3 (content specified in attribute RT_CLASS_3, see IEC 61158–5–10, 6.3.4.2.2), and
- RT Class UDP (content specified in attribute RT_CLASS_UDP, see IEC 61158–5–10, 6.3.4.2.2).

RT CLASS UDP is an optional communication class. It can be used without and in combination with RT Class 1, 2, and 3. The support of communication classes is shown in Table 28.

Table 28 – Communication classes applicable in conformance classes

Communication classes	Conformance classes		
	A	B	C
RT_CLASS_1 [a]	Mandatory	Mandatory	Mandatory [e]
RT_CLASS_2 [b d]	–	–	Only for legacy nodes
RT_CLASS_3 [c]	–	–	Mandatory [d]
RT_CLASS_UDP	Optional	Optional	Optional

[a] Real-time (RT) without bandwidth allocation, Traffic Class GREEN.

[b] Isochronous real-time (IRT) with bandwidth allocation, Traffic Class ORANGE.

[c] Isochronous real-time (IRT) with bandwidth allocation, Traffic Class RED.

[d] The use of RT_CLASS_2 is not intended.

[e] Whether the support of RT_CLASS_1 is mandatory or optional depends on the GSD keyword "IsochroneModeRequired".

8.1.5.2 Communication performance parameters

The values are shown in Table 29.

NOTE The inter frame gap (12 octets at the transmitter and 8 octets at the receiver) of the IEEE 802.3 applies.

Table 29 – Communication performance parameters

Parameter	Value	Meaning
REDBeginSafetyMargin	Minimum: 0 ns Maximum: 1 640 ns	This performance parameter is a RT_CLASS_3 property.
MinSupportedFSO	Minimum: 1 120 ns Maximum: 5 000 ns	This performance parameter is a RT_CLASS_3 property.
MinRTC3Gap	Minimum: 1 120 ns Maximum: 2 000 ns	This performance parameter is a RT_CLASS_3 property.
REDEndSafetyMargin	0 ns	This performance parameter is a RT_CLASS_3 property.
MaxFrameStartTime	Minimum: 960 ns Maximum: 5 000 ns	This performance parameter is a RT_CLASS_1 / RT_CLASS_2 / RT_CLASS_UDP property.
MinNRTGap	Minimum: 960 ns Maximum: 2 000 ns	This performance parameter is a RT_CLASS_1 / RT_CLASS_2 / RT_CLASS_UDP property.

8.1.5.3 RT_CLASS_3 bridges

The values for RT_CLASS_3 bridges are shown in Table 30.

Table 30 – Parameters for RT_CLASS_3 bridges

Parameter	Value	Meaning
Max Retention Time	Mandatory ≥ 20 µs Optional < 4 ms	This performance parameter is a RT_CLASS_3 bridge property.
Frame send offset deviation	Mandatory ≤ 10 ns	This performance parameter is a RT_CLASS_3 bridge property.
SafetyMargin	0 ns ≤ Mandatory ≤ 100 ns	This performance parameter is a RT_CLASS_3 bridge property if FrameDataProperties.ForwardingMode := “Relative mode” is supported

8.1.5.4 Transmitter

8.1.5.4.1 RT_CLASS_3 transmitter

The values for a RT_CLASS_3 transmitter are shown in Table 31.

Table 31 – FrameSendOffset deviation

Parameter	Value	Meaning
Frame send offset deviation	Node with RT_CLASS_3 bridge Mandatory ≤ 10 ns End node [a] Recommended ≤ 10 ns	This performance parameter is a RT_CLASS_3 transmitter property.

[a] The value of the deviation shall be as low as needed to avoid any disturbance in a RT_CLASS_3 domain.

NOTE The deviation measureable on the MDI (media dependent interface) depends on the added jitter of the transition from the MAC, MII to MDI.

8.1.5.4.2 RT_CLASS_1 / RT_CLASS_UDP transmitter

The values for a RT_CLASS_1 / RT_CLASS_UDP transmitter are shown in Table 32.

Table 32 – FrameSendOffset deviation for RT_CLASS_1 / RT_CLASS_UDP

Parameter	Value	Meaning
Frame send offset deviation	Minimum (Less than 10 % of the used update interval [a]; 10 ms)	This performance parameter is a RT_CLASS_1 / RT_CLASS_UDP transmitter property.
[a] The update interval (UI) is calculated as UI = SCF × RR × 31,25 µs with the data from the used IOCR.		

NOTE The deviation measureable on the MDI (media dependent interface) depends on the added jitter of the transition from the MAC, MII to the MDI.

8.1.5.5 RT_CLASS_3 node

The values for a RT_CLASS_3 node are shown in Table 33.

Table 33 – Minimum FrameSendOffset

Parameter	Value	Meaning
Minimum frame send offset [a]	SendClockFactor ≥ 8: Mandatory ≤ 5 000 ns	This performance parameter is a RT_CLASS_3 transmitter, receiver and forwarder property.
	SendClockFactor < 8: Mandatory ≤ 2 000 ns	
[a] The real value, if lower is stated in the GSD keyword “MinFSO”.		

8.1.5.6 Synchronization for RT_CLASS_3

The performance parameters of a PTCP control loop are shown in Table 34.

Table 34 – PTCP control loop

Parameter	Value	Meaning
Allowed frequency changing speed	Mandatory $\leq 5 \frac{\mu\text{Hz}}{\text{Hz}}/s$	This performance parameter is a sync slave property.

8.1.5.7 Fragmentation

Table 35 shows the allowed maximum frame size in the GREEN or YELLOW period transmitted by a node. This definition does not apply for nodes with FragmentationType == Dynamic.

Table 35 – Maximum frame size

SendClockFactor	Condition	Maximum frame size
1 – 2	FragmentationType [a] == Static	128 octets
3 – 7	FragmentationType [a] == Static	256 octets
8 – 128	FragmentationType [a] == Static && FrameDetails.FragmentationMode == Fragmentation enabled	
	! FragementationType [a] || FrameDetails.FragmentationMode == Fragmentation disabled	Maximum IEEE 802.3 frame
[a] See GSDML specification for the definition of this keyword.		

8.1.6 Media redundancy classes

Media redundancy classes are:

- RED_CLASS_1:

  Loop prevention and ring redundancy for IEEE 802 and IETF communications combined with the RTE specific additions RT_CLASS_1 and RT_CLASS_UDP (see 8.1.4).

  Class behavior distinguishes between manager and client as specified in IEC 61158-5-10, 6.3.3.
- RED_CLASS_3:

  Loop prevention and ring redundancy for IEEE 802 and IETF communications in conjunction with seamless media redundancy for rings with RT_CLASS_3.

NOTE 1 RED_CLASS_1 is called media redundancy protocol (MRP) and used in conjunction with RT_CLASS_1 and RT_CLASS_3. RED_CLASS_3 is called media redundancy for planned duplication (MRPD) and used in conjunction with RT_CLASS_3.

NOTE 2 RED_CLASS_3 offers ring redundancy and needs a protocol for loop prevention. RED_CLASS_1 offers loop prevention. That’s why RED_CLASS_3 inherits RED_CLASS_1.

Support of media redundancy requires devices with at least 2 ports; usage is shown in Table 36.

Table 36 – Media redundancy class applicable in conformance classes

Media redundancy classes	Conformance classes					
	A		B		C	
	Client	Manager [a]	Client	Manager [a]	Client	Manager [a]
RED_CLASS_1	Optional	Optional	Optional	Optional	Optional	Optional
RED_CLASS_3	–	–	–	–		
[a] One node in a ring shall support the manager role if one of the media redundancy classes is used.						

8.1.7 Media classes

Media classes are:

- Wired
- Fiber optic

- Wireless

If an interface uses media class “wireless”, the definitions made for media class “wired” may not apply.

8.1.8 Application classes

8.1.8.1 Definition

Devices supporting a specific application class shall support additional features beyond those required for the particular conformance class. Those features are described below in detail for the specific application class.

The following application classes are defined:

- Isochronous application (e.g. motion control)

NOTE Isochronous clock synchronization is a communication class feature and not an application class feature.

- Process automation
- High performance
- Controller to controller

The support of application classes is shown in Table 37 and Table 38:

Table 37 – Application classes applicable in conformance classes for IO device and IO controller

Application classes	Conformance classes		
	A	B	C
Isochronous application	–	–	Optional
Process automation	Optional [a]	Optional	Optional
High performance	–	–	Optional
Controller to controller	–	Optional	Optional

[a] Not recommended

Table 38 – Application classes applicable in conformance classes for network components

Application classes	Conformance classes		
	A	B	C
Isochronous application	–	–	–
Process automation	–	–	–
High performance	–	–	–
Controller to controller	–	–	–

8.1.8.2 Application class “Isochronous application”

Devices (i.e. IO device and IO controller) supporting the application class “isochronous application” shall support the following services additionally to the ones selected by the appropriate conformance class.

Application layer services for a device are defined in IEC 61158–5–10. Table 39 holds the application layer service selections from IEC 61158–5–10 to be supported additionally for this application class.

Table 39 – Application class “isochronous application” AL service selection

Clause	Header	Presence	Constraints
8.3.7	Isochronous Mode Application ASE	YES	–

Application layer protocols for a device are defined in IEC 61158–6–10. Table 40 holds the application layer protocol selections from IEC 61158–6–10 to be supported additionally for this application class.

Table 40 – Application class “isochronous application” AL protocol selection component

Clause	Header	Presence	Constraints
–	–	–	–

8.1.8.3 Application class “Process automation”

Devices (i.e. IO device and IO controller) supporting the application class “process application” shall support the following services additionally to the ones selected by the appropriate conformance class.

Application layer services for a device are defined in IEC 61158–5–10. Table 41 holds the application layer service selections from IEC 61158–5–10 to be supported additionally for this application class.

Table 41 – Application class “process automation” AL service selection

Clause	Header	Presence	Constraints
8.3.5	Alarm ASE	YES	System Redundancy alarm is mandatory
8.3.6	Context ASE	YES	ARType IOCAR_SR and service Prm Begin shall be supported
8.3.9	AR ASE	YES	AR switchover (backup, primary) shall be supported

Application layer protocols for a device are defined in IEC 61158–6–10. Table 42 holds the application layer protocol selections from IEC 61158–6–10 to be supported additionally for this application class.

Table 42 – Application class “process automation” AL protocol selection component

Clause	Header	Presence	Constraints
–	–	–	–

The support of time synchronization according to IEEE 802.1AS is mandatory for devices with more than one port and optional for devices with one port.

The support of media redundancy class RED_CLASS_1 is mandatory and RED_CLASS_3 is optional (see 8.1.6 for details).

IO devices shall support at least one AR set.

8.1.8.4 Application class “High performance”

Devices (i.e. IO device and IO controller) supporting the application class “High performance” shall support the following values shown in Table 43 and Table 44.

Table 43 – Application class “High performance” features supported

Parameter	Value	Meaning
SendClockFactor	Less than 8	Communication cycles less than 250 μs
FastForwarding	Supported	–
Fragmentation	Supported	–
Preamble shortening	Supported	–
Dynamic frame packing	Supported	–

Table 44 – Application class “High performance” parameter values

Parameter	Value	Meaning
REDBeginSafetyMargin	160 ns	–
MinSupportedFSO	Maximum: 2 μs	–
MinRTC3Gap	1 120 ns	–
REDEndSafetyMargin	0 ns	–
MaxFrameStartTime	Maximum: 2 μs	–
MinNRTGap	960 ns	–
BridgeDelay	Maximum: 1 μs	–
MaxPortTxDelay	Maximum: 90 ns	–
MaxPortRxDelay	Maximum: 210 ns	–
MaxDFP_Feed	Maximum: 500 ns	–
Peer to peer jitter	Maximum: 250 ns	–
NOTE All times are specified for FastForwarding and ShortPreamble mode.		

8.1.8.5 Application class “Controller to controller”

Devices supporting the application class “Controller to controller” shall support the following values shown in Table 45.

Table 45 – Application class “Controller to controller” features supported

Parameter	Value	Meaning
IO controller	YES	–
IO device	YES	–
Controller to controller records	YES	Index range 0xF860 to 0xF86F Retrieval of the stored GSD shall be supported
IO controller Record data CR	16 588 octets	minimal 16 588 octets data length (length of the *PROFINETIOServiceReqPDU or PROFINETIOServiceResPDU*)
Shared IO device support	YES	–
Shared Input support	YES	–
Number of ARs	4	The IO device shall support at least four concurrent ARs

8.1.9 Records

8.1.9.1 General

Different records are associated with conformance class A, B and C as shown in Table 46, Table 47, Table 48, Table 49, Table 50, and Table 51.

Table 46 – Index (user specific)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0 – 0x7FFF	User specific RecordData	O		O		O	

R Read
W Write
M Mandatory
O Optional
G Defined by the general station description (GSD)

Table 47 – Index (subslot specific)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0x8000	ExpectedIdentificationData for one subslot	M	–	M	–	M	–
0x8001	RealIdentificationData for one subslot	M	–	M	–	M	–
0x8002 – 0x8009	Reserved	–					
0x800A	Diagnosis in channel coding for one subslot	M	–	M	–	M	–
0x800B	Diagnosis in all codings for one subslot	M	–	M	–	M	–
0x800C	Diagnosis, Maintenance, Qualified and Status for one subslot	M	–	M	–	M	–
0x800D – 0x800F	Reserved	–					
0x8010	Maintenance required in channel coding for one subslot	M	–	M	–	M	–
0x8011	Maintenance demanded in channel coding for one subslot	M	–	M	–	M	–
0x8012	Maintenance required in all codings for one subslot	M	–	M	–	M	–
0x8013	Maintenance demanded in all codings for one subslot	M	–	M	–	M	–
0x8014 – 0x801D	Reserved	–					
0x801E	SubstituteValues for one subslot	G		G		G	
0x801F	Reserved	–					
0x8020	PDIRSubframeData for one subslot	–		–		G	
0x8021 – 0x8027	Reserved	–					
0x8028	RecordInputDataObjectElement for one subslot	M	–	M	–	M	–
0x8029	RecordOutputDataObjectElement for one subslot	M	–	M	–	M	–
0x802A	PDPortDataReal for one subslot	M	–	M	–	M	–
0x802B	PDPortDataCheck for one subslot	M		M		M	
0x802C	PDIRData for one subslot	–		–		M	
0x802D	Expected PDSyncData for one subslot with SyncID value 0	–		G		M	
0x802E	Reserved (legacy)	–					
0x802F	PDPortDataAdjust for one subslot	G		G		G	
0x8030	IsochronousModeData for one subslot	–		–		G	
0x8031	Expected PDTimeData for one subslot	–		G		G	
0x8032 – 0x804F	Reserved (legacy)	–		–		–	

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0x8050	PDInterfaceMrpDataReal for one subslot	G	–	G	–	G	–
0x8051	PDInterfaceMrpDataCheck for one subslot	G		G		G	
0x8052	PDInterfaceMrpDataAdjust for one subslot	G		G		G	
0x8053	PDPortMrpDataAdjust for one subslot	G		G		G	
0x8054	PDPortMrpDataReal for one subslot	G	–	G	–	G	–
0x8055 – 0x805F	Reserved	–					
0x8060	PDPortFODataReal for one subslot	G	–	G	–	G	–
0x8061	PDPortFODataCheck for one subslot	G		G		G	
0x8062	PDPortFODataAdjust for one subslot	G		G		G	
0x8063 – 0x806F	Reserved	–					
0x8070	PDNCDataCheck for one subslot	G		G		G	
0x8071	PDInterfaceAdjust for one subslot	G		G		G	
0x8072	PDPortStatistic for one subslot	O	–	M	–	M	–
0x8073 – 0x807F	Reserved	–					
0x8080	PDInterfaceDataReal for one subslot	M	–	M	–	M	–
0x8081 – 0x808F	Reserved	–					
0x8090	Expected PDInterfaceFSUDataAdjust	G		G		G	
0x8091 – 0x909F	Reserved	–					
0x80A0	Profiles covering energy saving – Record_0	G		G		G	
0x80A1 – 0x80AF	Reserved for profiles covering energy saving	–					
0x80B0	CombinedObjectContainer	G		G		G	
0x80B1 – 0x80BF	Reserved	–					
0x80C0	Profiles covering sequence of events – Record_0	G		G		G	
0x80C1 – 0x80CF	Reserved for profiles covering sequence of events	–					
0x80D0 – 0xAFEF	Reserved	–					
0xAFF0	I&M0	M	–	M	–	M	–
0xAFF1	I&M1 [b c]	O	G	O	G	O	G
0xAFF2	I&M2 [b c]	O	G	O	G	O	G
0xAFF3	I&M3 [b c]	O	G	O	G	O	G
0xAFF4	I&M4 [b c]	O	G	O	G	O	G
0xAFF5 – 0xAFFF	I&M5 – I&M15	O		O		O	
0xB000 – 0xBFFF	Reserved for profiles	O		O		O	

R Read
W Write
M Mandatory
O Optional
G Defined by the general station description (GSD)

[a] –
[b] If defined writeable by GSD also readable.
[c] Mandatory, read- and writeable, for at least one submodule, e.g. interface submodule.

It is not necessary for a device application to generate diagnosis, maintenance, qualified or status information.

However the data records 0x800A, 0x800B, 0x800C, 0x8010, 0x8011, 0x8012 and 0x8013 act as a filter to the diagnosis ASE. If the diagnosis ASE does not contain any information of the requested type(s), the data record shall be returned empty. It is not allowed to state that the record does not exist.

Table 48 – Index (slot specific)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0xC000	ExpectedIdentificationData for one slot	M	–	M	–	M	–
0xC001	RealIdentificationData for one slot	M	–	M	–	M	–
0xC002 – 0xC009	Reserved	–					
0xC00A	Diagnosis in channel coding for one slot	M	–	M	–	M	–
0xC00B	Diagnosis in all codings for one slot	M	–	M	–	M	–
0xC00C	Diagnosis, Maintenance, Qualified and Status for one slot	M	–	M	–	M	–
0xC00D – 0xC00F	Reserved	–					
0xC010	Maintenance required in channel coding for one slot	M	–	M	–	M	–
0xC011	Maintenance demanded in channel coding for one slot	M	–	M	–	M	–
0xC012	Maintenance required in all codings for one slot	M	–	M	–	M	–
0xC013	Maintenance demanded in all coding for one slot	M	–	M	–	M	–
0xC014 – 0xCFFF	Reserved	–					
0xD000 – 0xDFFF	Reserved for profiles	O		O		O	
R Read W Write M Mandatory O Optional G Defined by the general station description (GSD)							

Table 49 – Index (AR specific)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0xE000	ExpectedIdentificationData for one AR	M	–	M	–	M	–
0xE001	RealIdentificationData for one AR	M	–	M	–	M	–
0xE002	ModuleDiffBlock for one AR	M	–	M	–	M	–
0xE003 – 0xE009	Reserved	–					
0xE00A	Diagnosis in channel coding for one AR	M	–	M	–	M	–
0xE00B	Diagnosis in all codings for one AR	M	–	M	–	M	–
0xE00C	Diagnosis, Maintenance, Qualified and Status for one AR	M	–	M	–	M	–
0xE00D – 0xE00F	Reserved	–					
0xE010	Maintenance required in channel coding for one AR	M	–	M	–	M	–
0xE011	Maintenance demanded in channel coding for one AR	M	–	M	–	M	–
0xE012	Maintenance required in all codings for one AR	M	–	M	–	M	–
0xE013	Maintenance demanded in all codingsfor one AR	M	–	M	–	M	–
0xE014 – 0xE02F	Reserved	–					

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0xE030	Reserved	–					
0xE031 – 0xE03F	Reserved	–					
0xE040	MultipleWrite [b]	–	M	–	M	–	M
0xE041 – 0xE04F	Reserved	–					
0xE050	Legacy ARFSUDataAdjust [a] data for one AR	– G [a]					
0xE051 – 0xE05F	Reserved for FastStartUp	–					
0xE060 – 0xEBFF	Reserved	–					
0xEC00 – 0xEFFF	Reserved for profiles	O	–	O	–	O	–

R Read
W Write
M Mandatory
O Optional
G Defined by the general station description (GSD)

[a] The record ARFSUDataAdjust is supported only, when using legacy startup mode.
[b] The GSDML shall state the support of this feature.

Table 50 – Index (API specific)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0xF000	RealIdentificationData for one API	M	–	M	–	M	–
0xF001 – 0xF009	Reserved	–					
0xF00A	Diagnosis in channel coding for one API	M	–	M	–	M	–
0xF00B	Diagnosis in all codings for one API	M	–	M	–	M	–
0xF00C	Diagnosis, Maintenance, Qualified and Status for one API	M	–	M	–	M	–
0xF00D – 0xF00F	Reserved	–					
0xF010	Maintenance required in channel coding for one API	M	–	M	–	M	–
0xF011	Maintenance demanded in channel coding for one API	M	–	M	–	M	–
0xF012	Maintenance required in all codings for one API	M	–	M	–	M	–
0xF013	Maintenance demanded in all codings for one API	M	–	M	–	M	–
0xF014 – 0xF01F	Reserved	–					
0xF020	ARData for one API	M	–	M	–	M	–
0xF021 – 0xF3FF	Reserved	–					
0xF400 – 0xF7FF	Reserved for profiles	O	–	O	–	O	–

R Read
W Write
M Mandatory
O Optional
G Defined by the general station description (GSD)

Table 51 – Index (device specific)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0xF800 – 0xF80B	Reserved	–					
0xF80C	Diagnosis, Maintenance, Qualified and Status for one device	M	–	M	–	M	–
0xF80D – 0xF81F	Reserved	–					
0xF820	ARData	M	–	M	–	M	–
0xF821	APIData	M	–	M	–	M	–
0xF822 – 0xF82F	Reserved	–					
0xF830	LogBookData	M	–	M	–	M	–
0xF831	PDevData	–		O	–	O	–
0xF832 – 0xF83F	Reserved	–					
0xF840	I&M0FilterData	M	–	M	–	M	–
0xF841	PDRealData	M	–	M	–	M	–
0xF842	PDExpectedData	M	–	M	–	M	–
0xF843 – 0xF84F	Reserved	–					
0xF850	AutoConfiguration	G	–	G	–	G	–
0xF851 – 0xF85F	Reserved	–					
0xF860	Controller to controller communication GSD upload using UploadBLOBQuery and UploadBLOB	G	–	G	–	G	–
0xF861	Controller to controller communication Nested diagnosis info	G	–	G	–	G	–
0xF862 – 0xF86E	Reserved for Controller to controller communication 2…14	–					
0xF86F	Reserved for Controller to controller communication 15	G	–	G	–	G	–
0xF870 – 0xFBFE	Reserved	–					
0xFBFF	Trigger index for the RPC connection monitoring	M	–	M	–	M	–
0xFC00 – 0xFFFF	Reserved for profiles	O	–	O	–	O	–
R Read W Write M Mandatory O Optional G Defined by the general station description (GSD)							

8.1.9.2 Record sub blocks

8.1.9.2.1 General

The following definitions applies if the protocol is defined for the implemented MAU type of the affected port.

8.1.9.2.2 PDPortDataAdjust

Different sub blocks of the PDPortDataAdjust record are associated with conformance class A, B and C as shown in Table 52.

Table 52 – PDPortDataAdjust (sub blocks)

Value (hexadecimal)	Meaning of sub block	Conformance class					
		A		B		C	
		R	W	R	W	R	W
–	AdjustDomainBoundary	–		M [a]		M	
–	AdjustMulticastBoundary	–		M [b]			
–	AdjustMAUType	G				M	
–	AdjustLinkState	G				M	
–	AdjustPeerToPeerBoundary	M [c]		M [d]		M [e]	
–	AdjustDCPBoundary	M					
–	AdjustPreambleLength	–				M [f]	

R Read
W Write
M Mandatory
O Optional
G Defined by the general station description (GSD)

[a] Mandatory if PTCP is supported
[b] Mandatory if Multicast Communication relation is supported
[c] Only LLDP boundary is mandatory
[d] LLDP and if supported PTCP and IEEE 802.1AS; these boundaries are mandatory
[e] LLDP, PTCP and if supported IEEE 802.1AS; these boundaries are mandatory
[f] Mandatory if the performance profile applies

8.1.9.2.3 PDPortDataCheck

Different sub blocks of the PDPortDataCheck record are associated with conformance class A, B and C as shown in Table 53.

Table 53 – PDPortDataCheck (sub blocks)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
–	CheckPeers	M					
–	CheckLineDelay	–		M [a]		M	
–	CheckMAUType	G				M	
–	CheckLinkState	G				M	
–	CheckSyncDifference	–		M [a]		M	
–	CheckMAUTypeDifference	M					

R Read
W Write
M Mandatory
O Optional
G Defined by the general station description (GSD)

[a] Mandatory if PTCP is supported

8.1.10 Communication feature list

Table 54 shows at a glace a list of PROFINET features.

Table 54 – Communication feature list

Feature	Conformance Classes		
	A	B	C
Provider for multicast communication relation (MCR)	Optional		
Shared device	Optional		
Shared input	Optional		
Fast startup	Optional		
Device access	Optional		
Supervisor Application Relation	IO controller: – IO device: Recommended		
Implicit Application Relation	IO controller: Optional IO device: Mandatory		
AutoNameOfStationAssignment See CTLDINA in IEC 61158–6–10	IO controller: Recommended IO device: –		

8.1.11 Conformance class behaviors

CP 3/4, CP 3/5, and CP 3/6 specify the different node classes in the CPF 3 subclauses. The application classes are selected in conformance class. A CP is associated to a conformance class. Media redundancy is selected in a conformance class. Table 55 specifies the required conformance class behaviors.

In this document the following communication profiles are specified for CPF 3:

- CP 3/4, see Table 55 and Table 57 conformance class **A**;
- CP 3/5, see Table 55 conformance class **B**;
- CP 3/6, see Table 55 conformance class **C**.

Table 55 – Conformance class behaviors

General classes	Conformance Classes			
	A		B	C
	Wireless	Wired		
CP	CP 3/4		CP 3/5	CP 3/6
Node classes [a] (see 8.1.3)	IO device, IO controller			
Media classes (see 8.1.7)	Wireless	Selection of wired or fiber optic		
Application classes	see 8.1.8			
Communication classes [b]	see 8.1.5			
Media redundancy classes	–	see 8.1.6		
Installation IEC 61784–5–3	–	Optional	YES	
Communication feature list	see 8.1.10			
IEEE 802.3	–	YES [i]		
IEEE 802.1D	–	YES [c]		YES [g]
IEEE 802.1Q	–	YES [d]		
IEEE 802.1AB	Optional	YES [f]	YES	

General classes	Conformance Classes			
	A		B	C
	Wireless	Wired		
IEEE 802.1AS	Optional			
Wireless technologies selection	1. IEEE 802.11 [e] 2. IEEE 802.15.1	–	–	–
SNMP	Optional		YES	
LLDP-MIB [j] LLDP-EXT-DOT1-MIB LLDP-EXT-DOT3-MIB LLDP-EXT-PNIO-MIB	Optional	YES [f]	YES	
MIB-II	Optional		YES [h]	
PNIO MIB	Optional			

[a] IO supervisor are out of scope of conformance class.

[b] All conformance classes allow IETF communication combined with the RTE specific additions. The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.

[c]
1) RSTP optional or replaced by MRP. .
2) CutThroughMode is recommended.
3) “Discard on received frame in error” is optional when using the CutThroughMode.
4) At least two priorities required (4 recommended).

[d] Priority tagging VLAN configuration, removal and modification of tag headers is optional.

[e]
1) IEEE 802.11 (At least EDCA part with four priorities supported)
2) Optional IEEE 802.11n.

[f] Sending and receiving of LLDP frames is mandatory. The support of the MIB is optional

[g]
1) RSTP optional or replaced by MRP.
2) CutThroughMode is mandatory.
3) “Discard on received frame in error” optional (CutThroughMode).
4) At least two priorities required (4 recommended).

[h] See Table 56.

[i] The support of Auto Negotiation with a link speed of at least 100 Mbit/s full-duplex is mandatory. All other MAU types stated in RFC 4836 fulfilling this requirements (i.e. 1 Gbit/s full-duplex, 10 Gbit/s or 100 Gbit/s full-duplex) is optional.

[j] The LLDP-MIB uses version LLDP-MIB-200505060000Z.MIB and their extensions.

Table 56 – MIB-II objects

OID tree entry	Object identification	Meaning
iso(1). org (3). dod(6). internet(1). mgmt(2). mib-2(1). system(1).	sysDescr(1), sysObjectID(2), sysUpTime(3), sysContact(4), sysName(5), sysLocation(6), sysServices(7)	Mandatory for “conformance class **B**” and “conformance class **C**”.
iso(1). org (3). dod(6). internet(1). mgmt(2). mib-2(1). interfaces(2).	ifNumber	Mandatory if multiple interfaces is supported. Recommended for “conformance class **B**” and “conformance class **C**”.
iso(1). org (3). dod(6). internet(1). mgmt(2). mib-2(1). interfaces(2). ifTable(2). ifEntry.	ifIndex(1), ifDescr(2), ifType(3), ifMtu(4), ifSpeed(5), ifPhysAddress(6), ifAdminStatus(7), ifOperStatus(8)	Mandatory if multiple interfaces is supported. Recommended for “conformance class **B**” and “conformance class **C**”.
iso(1). org (3). dod(6). internet(1). mgmt(2). mib-2(1). interfaces(2). ifTable(2). ifEntry.	ifLastChange(9), ifInOctets(10), ifInUcastPkts(11), ifInNUcastPkts(12), ifInDiscards(13), ifInErrors(14), ifInUnknownProtos(15), ifOutOctets(16), ifOutUcastPkts(17), ifOutNUcastPkts(18), ifOutDiscards(19), ifOutErrors(20), ifOutQLen(21), ifSpecific(22)	Recommended for “conformance class **B**” and “conformance class **C**”.

The conformance classes are laid out in such a way that a lower conformance class is a subset of a higher conformance class. Thus higher class devices are interoperable with lower class devices by using the capabilities of the lower class only (e.g. by using RT_CLASS_1).

However, a particular submodule of an IO device may enforce the IO controller to use isochronous mode operation (indicated with the GSDML keyword IsochroneModeRequired) and thus in consequence enforces the IO controller to use conformance class C. Such an IO device with that particular submodule will not be able to operate on an IO controller supporting a lower conformance class than C.

Table 57 – Conformance class behaviors for network components

General classes	Conformance Classes		
	A	**A**	**A**
CP	CP 3/4	CP 3/4	CP 3/4
Node classes (see 8.1.3)	Switch	Wireless access point	Wireless client
Media classes (see 8.1.7)	Selection of wired or fiber optic	Wireless	Wireless
Application classes	see 8.1.8		
Communication classes [a] (see 8.1.5)	–	–	–
Media redundancy classes	see 8.1.6	–	–
Installation IEC 61784–5–3	Optional	–	–
Communication feature list	–	–	–
IEEE 802.3	YES[e]	–	–
IEEE 802.1D	YES[b]	–	–
IEEE 802.1Q	YES[c]	–	–
IEEE 802.1AB	Recommended	Optional	Optional
IEEE 802.1AS	Optional	Optional	Optional
Wireless technologies selection	–	1. IEEE 802.11 [d] 2. IEEE 802.15.1	1. IEEE 802.11 [d] 2. IEEE 802.15.1
IEEE 802.11	–	YES [f]	YES [f]
SNMP	Recommended	Optional	Optional
MIB-II	Recommended	Optional	Optional
LLDP-MIB [g] LLDP-EXT-DOT1-MIB LLDP-EXT-DOT3-MIB LLDP-EXT-PNIO-MIB	Recommended	Optional	Optional

[a] All conformance classes allow IETF communication combined with the RTE specific additions. The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.

[b]
1) RSTP optional or replaced by MRP .
2) CutThroughMode is recommended.
3) “Discard on received frame in error” is optional when using the CutThroughMode.
4) At least two priorities required (4 priorities recommended).

[c] Priority tagging VLAN configuration, removal and modification of tag headers is optional.

[d] Optional IEEE 802.11n.

[e] The support of Auto Negotiation with a link speed of at least 100 Mbit/s full-duplex is mandatory. All other MAU types stated in RFC 4836 fulfilling this requirements (i.e. 1 Gbit/s full-duplex, 10 Gbit/s or 100 Gbit/s full-duplex) is optional.

[f] At least EDCA part with four priorities shall be supported.

[g] The LLDP-MIB using version LLDP-MIB-200505060000Z.MIB and their extensions.

Network components can be used as leaves of a CP 3/6 network to connect CP 3/4 or CP 3/5 devices without loosing the **C** conformance class capabilities. An example of connecting CP 3/4, CP 3/5, and CP 3/6 together is shown in Figure 3.

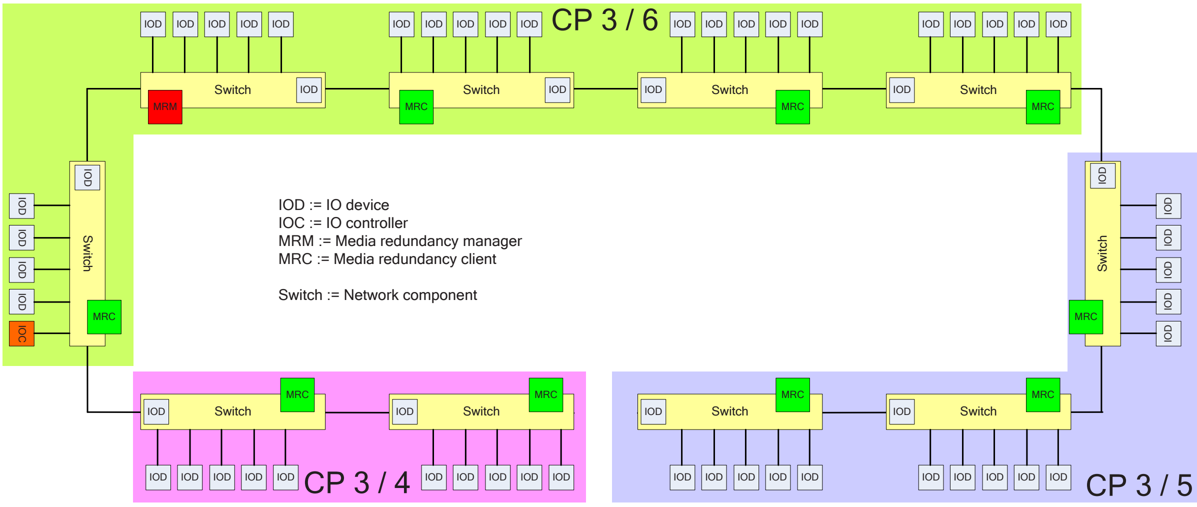

Figure 3 – Example of network topology using CP 3/4, CP 3/5, and CP 3/6 components

8.2 Profile 3/4

8.2.1 Physical layer

8.2.1.1 Media class wired and fiber optic

The physical layer shall be according to IEEE 802.3.

The data rate shall be at least 100 Mbit/s and full-duplex mode shall be used at least for one port.

Devices shall comply with the legal requirements of that country where they are deployed (for example, as indicated by the CE mark). The measures for protection against electrical shocks (i.e. electrical safety) within industrial applications shall be based on the IEC 61010 series or IEC 61131-2 depending on device type specified therein.

8.2.1.2 Media class wireless

The physical layer shall be a selection of IEEE 802.11 and IEEE 802.15.1.

If IEEE 802.11 is selected then the data rate shall be according to IEEE 802.11 and optional according to IEEE 802.11n, else the data rate shall be according IEEE 802.15.1.

8.2.2 Data link layer

8.2.2.1 General

It is recommended to limit the local injected non real time traffic of each node to 3 Koctets per millisecond to avoid a network overload.

8.2.2.2 Media class wired and fiber optic

The data link layer shall be according to IEEE 802.3, IEEE 802.1AB, IEEE 802.1D, and IEEE 802.1Q.

All management information bases (MIBs) are optional.

8.2.2.3 Media class wireless

The data link layer shall be a selection of IEEE 802.11 or IEEE 802.15.1.

Devices of the media class wireless using the IEEE 802.15.1 physical layer shall support adaptive frequency hopping (AFH). Furthermore these devices shall provide means to exclude frequencies used by IEEE 802.11 systems permanently from their hopping sequence.

All management information bases (MIBs) are optional.

8.2.3 Application layer

8.2.3.1 AL service selection

8.2.3.1.1 IO device

Application layer services for an IO device are defined in IEC 61158–5–10. Table 58 holds the application layer service selections from IEC 61158–5–10 for this profile.

Table 58 – CP 3/4: AL service selection for an IO device

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Concepts	YES	–
5	Data type ASE	YES	–
6	Communication model for common services	–	–
6.1	Concepts	YES	–
6.2	ASE data types	YES	–
6.3	ASEs	–	–
6.3.1	Discovery and basic configuration ASE	YES	–
6.3.2	Precision time control ASE	YES	Optional
6.3.3	Media redundancy ASE	YES	See 8.1.6, n.a. for wireless media
6.3.4	Real-time cyclic ASE	YES	RT_CLASS_UDP is optional
6.3.5	Real-time acyclic ASE	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.6	Remote procedure call ASE	YES	–
6.3.7	IEEE 802.1AB ASE	YES	n.a. for wireless media
6.3.8	IEEE 802.1AS ASE	YES	Optional
6.3.9	IEEE 802.1D ASE	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
6.3.10	IEEE 802.1Q ASE	YES	n.a. for wireless media
6.3.11	IEEE 802.3 ASE	YES	n.a. for wireless media
6.3.12	Fragmentation ASE	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
6.3.13	IP suite ASE	YES	ICMP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.14	Domain name system ASE	YES	Optional
6.3.15	Dynamic host configuration ASE	YES	Optional
6.3.16	Simple network management ASE	YES	Optional
6.3.17	Common DL Mapping ASE	–	–
6.3.17.1	Overview	YES	–

Clause	Header	Presence	Constraints
6.3.17.2	DL Mapping class specification	YES	–
6.3.17.3	DL Mapping service specification	–	–
6.3.17.3.1	P Data	YES	Optional; mandatory if Precision Time Control ASE is supported
6.3.17.3.2	N Data	YES	–
6.3.17.3.3	A Data	YES	–
6.3.17.3.4	C Data	YES	–
7	Communication model for decentralized periphery	–	–
7.1	Concepts	YES	–
7.2	ASE data types	YES	–
7.3	ASEs	–	–
7.3.1	Record Data ASE	YES	–
7.3.2	IO Data ASE	YES	–
7.3.3	LogBook Data ASE	YES	–
7.3.4	Diagnosis ASE	YES	–
7.3.5	Alarm ASE	YES	–
7.3.6	Context ASE	YES	–
7.3.7	Isochronous Mode Application ASE	NO	–
7.3.8	Physical Device Management ASE	YES	–
7.3.9	AR ASE	YES	–
7.4	Behavior of an IO device	–	–
7.4.1	Overview	YES	–
7.4.2	Startup of an IO device	YES	–
7.4.3	Physical device parameter check	–	–
7.4.3.1	General	YES	–
7.4.3.2	Remote system data	YES	–
7.4.3.3	Local system data	YES	–
7.4.3.4	Optical system data	YES	Optional; mandatory if fiber optic is used
7.4.4	Diagnosis and problem indicator	YES	–
7.4.5	User alarms	YES	–
7.4.6	Behavior in case of configuration change	YES	–
7.4.7	Behavior for PTCP within IO devices	YES	Optional; mandatory if precision time control ASE (see 6.3.2) is supported
7.5	Behavior of an IO controller	NO	–
7.6	Application characteristics	YES	–
Annex A	Device instances	YES	–
Annex B	Components of an Ethernet interface	Partial	Used when applicable
Annex C	Scheme of MAC address assignment	YES	–
Annex D	Collection of objects	YES	–
Annex E	Measurement of the fast startup time	YES	–
Annex F	Dynamic Frame Packing	YES	Optional
Annex G	Building IR Data	YES	Optional; mandatory if RT_CLASS_3 is used

8.2.3.1.2 Network component

8.2.3.1.2.1 General

A network component can be integrated in an IO device or an IO controller. If so, then the requirements of an IO device and IO controller are applicable.

Alternatively the network component can be build as a non-integrated network component as a stand alone node.

A 100 Mbit/s switch should support a buffering of all data of at least 1 ms. This should be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

A 100 Mbit/s switch with less than eight ports shall provide buffering capacity according to Table 69, with eight and more ports according to Table 70. This shall be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

8.2.3.1.2.2 Non-integrated network component

A non-integrated network component does not require Type 10 AL. Table 57 specifies the general network component behaviors.

The wireless bridge (2 access points or 1 access point and 1 client) shall support less then 128 ms propagation delay. An example of a wireless topology is shown in Figure 4.

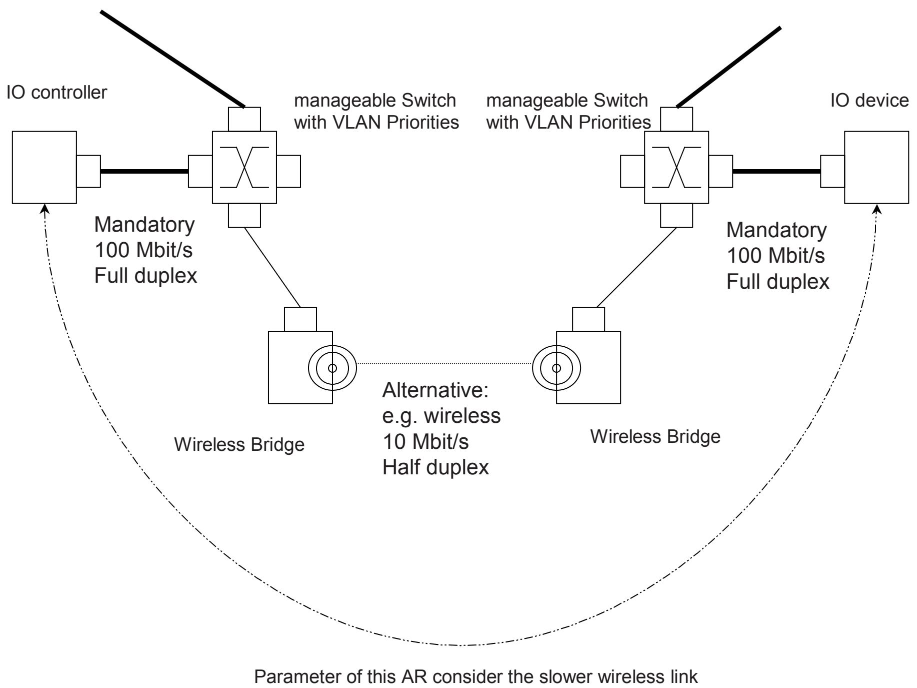

Figure 4 – Example of network topology with wireless segment

8.2.3.1.2.3 Integrated network component

Application layer services for a network component are defined in IEC 61158–5–10. Table 58 holds the application layer service selections from IEC 61158–5–10 for this profile.

8.2.3.1.3 IO controller

Application layer services for an IO controller are defined in IEC 61158–5–10. Table 58 holds the application layer service selections from IEC 61158–5–10 for this profile except 7.4 is NO and 7.5 is YES.

8.2.3.1.4 IO supervisor

See 8.2.3.1.3.

8.2.3.1.5 Options

DHCP according to RFC 2131 is an optional service.

DNS is an optional service for an IO controller and IO supervisor.

Media redundancy (see 8.1.6).

PTCP is an optional service. If PTCP is supported, the support of both sync master and redundant sync master are optional for an IO device. For an IO controller the support of sync master is mandatory and the support of redundant sync master optional.

8.2.3.2 AL protocol selection

8.2.3.2.1 IO device

Application layer protocols for an IO device are defined in IEC 61158–6–10. Table 59 holds the application layer protocol selections from IEC 61158–6–10 for this profile.

Table 59 – CP 3/4: AL protocol selection for an IO device and Network component

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Application Layer protocol specification for common protocols	–	–
4.1	FAL syntax description	YES	–
4.2	Transfer syntax	–	–
4.2.1	Coding of basic data types	Partial	Used as needed
4.2.2	Coding section related to common basic fields	Partial	Used as needed
4.3	Discovery and basic configuration	YES	–
4.4	Precision working time control	YES	Optional, n.a. for wireless media
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real-time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real-time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
4.10	Remote procedure call	YES	–

Clause	Header	Presence	Constraints
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	MAC bridges	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
4.13	Virtual bridges	YES	n.a. for wireless
4.14	IP suite	YES	–
4.15	Domain name system	YES	Optional
4.16	Dynamic host configuration	YES	Optional
4.17	Simple network management	YES	Optional
4.18	Common DLL Mapping Protocol Machines	YES	–
5	Application Layer protocol specification for decentralized periphery	–	–
5.1	FAL syntax description	YES	–
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	–
5.5	FAL Service Protocol Machines	–	–
5.5.1	Overview	YES	–
5.5.2	FAL Service Protocol Machine Device	YES	–
5.5.3	FAL Service Protocol Machine Controller	NO	–
5.6	Application Relationship Protocol Machines	–	–
5.6.1	Alarm Protocol Machine Initiator	YES	–
5.6.2	Alarm Protocol Machine Responder	YES	–
5.6.3	Device	YES	–
5.6.4	Controller	NO	–
5.7	DLL Mapping Protocol Machines	YES	–
Annex A	Unified establishing of an AR for all RT classes	YES	–
Annex B	Compatible establishing of an AR	YES	–
Annex C	Establishing of a device access AR	YES	–
Annex D	Establishing of an AR (accelerated procedure)	YES	–
Annex E	Establishing of an AR (fast startup procedure)	YES	–
Annex F	Example of the upload, storage and retrieval procedure	YES	–
Annex G	OSI reference model layers	YES	–
Annex H	Overview of the IO controller and the IO device state machines	YES	–
Annex I	Priority regeneration	YES	–
Annex J	Overview of the synchronization master hierarchy	YES	Optional; mandatory if Precision time control is supported
Annex K	Optimization of bandwith usage	YES	–
Annex L	Time constraints for bandwidth allocation	YES	Optional; mandatory if RT_CLASS_2 or RT_CLASS_3 are supported
Annex M	Time constraints for the forwarding of a frame	YES	–
Annex N	Principle of dynamic frame packing	YES	Optional

Clause	Header	Presence	Constraints
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	–
Annex S	TX-error handling	YES	–
Annex T	Example of a PrmBegin, PrmEnd and ApplRdy procedure	YES	–
Annex U	List of supported MIBs	YES	Optional
Annex V	Structure and content of BLOB	YES	If needed
Annex W	LLDP EXT MIB	YES	Optional

8.2.3.2.2 Network component

8.2.3.2.2.1 General

See 8.2.3.1.2.1.

8.2.3.2.2.2 Non-integrated network component

A non-integrated network component does not require Type 10 AL. Table 57 specifies the general network component behaviors.

8.2.3.2.2.3 Integrated network component

Application layer protocols for an integrated network component are defined in IEC 61158-6-10. Table 59 specifies the clauses included in this profile.

8.2.3.2.3 IO controller

Application layer protocols for an IO controller are defined in IEC 61158–6–10. Table 60 specifies the clauses included in this profile.

Table 60 – CP 3/4: AL protocol selection for an IO controller

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Application Layer protocol specification for common protocols	–	–
4.1	FAL syntax description	YES	–
4.2	Transfer syntax	–	–
4.2.1	Coding of basic data types	Partial	Used as needed
4.2.2	Coding section related to common basic fields	Partial	Used as needed
4.3	Discovery and basic configuration	YES	–
4.4	Precision working time control	YES	Optional, n.a. for wireless media

Clause	Header	Presence	Constraints
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real-time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real-time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
4.10	Remote procedure call	YES	–
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	MAC bridges	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
4.13	Virtual bridges	YES	n.a. for wireless
4.14	IP suite	YES	–
4.15	Domain name system	YES	Optional
4.16	Dynamic host configuration	YES	Optional
4.17	Simple network management	YES	Optional
4.18	Common DLL Mapping Protocol Machines	YES	–
5	Application Layer protocol specification for decentralized periphery	–	–
5.1	FAL syntax description	YES	–
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	–
5.5	FAL Service Protocol Machines	–	–
5.5.1	Overview	YES	–
5.5.2	FAL Service Protocol Machine Device	NO	–
5.5.3	FAL Service Protocol Machine Controller	YES	–
5.6	Application Relationship Protocol Machines	–	–
5.6.1	Alarm Protocol Machine Initiator	YES	–
5.6.2	Alarm Protocol Machine Responder	YES	–
5.6.3	Device	NO	–
5.6.4	Controller	YES	–
5.7	DLL Mapping Protocol Machines	YES	–
Annex A	Unified establishing of an AR for all RT classes	YES	–
Annex B	Compatible establishing of an AR	YES	–
Annex C	Establishing of a device access AR	YES	–
Annex D	Establishing of an AR (accelerated procedure)	YES	–
Annex E	Establishing of an AR (fast startup procedure)	YES	–
Annex F	Example of the upload, storage and retrieval procedure	YES	–
Annex G	OSI reference model layers	YES	–

Clause	Header	Presence	Constraints
Annex H	Overview of the IO controller and the IO device state machines	YES	–
Annex I	Priority regeneration	YES	–
Annex J	Overview of the synchronization master hierarchy	YES	Optional; mandatory if Precision time control is supported
Annex K	Optimization of bandwith usage	YES	–
Annex L	Time constraints for bandwidth allocation	YES	Optional; mandatory if RT_CLASS_2 or RT_CLASS_3 are supported
Annex M	Time constraints for the forwarding of a frame	YES	–
Annex N	Principle of dynamic frame packing	YES	Optional
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	–
Annex S	TX-error handling	YES	–
Annex T	Example of a PrmBegin, PrmEnd and ApplRdy procedure	YES	–
Annex U	List of supported MIBs	YES	Optional
Annex V	Structure and content of BLOB	YES	If needed
Annex W	LLDP EXT MIB	YES	Optional

8.2.3.2.4 IO supervisor

See 8.2.3.1.4.

8.2.3.2.5 Options

DHCP according to RFC 2131 is an optional protocol.

DNS is an optional protocol for an IO controller and IO supervisor.

Media redundancy (see 8.1.6).

PTCP is an optional service. If PTCP is supported, the support of both sync master and redundant sync master are optional for an IO device. For an IO controller the support of sync master is mandatory and the support of redundant sync master optional.

RT_Class_UDP is optional.

8.2.4 Performance indicator selection

8.2.4.1 Performance indicator overview

Table 61 specifies the relevant performance indicators.

Table 61 – CP 3/4, CP 3/5 and CP 3/6: Performance indicator overview

Performance indicator	Applicable	Constraints
Delivery time	Yes	–
Number of end-stations	Yes	–
Basic network topology	Yes	–
Number of switches between end-stations	Yes	–
Throughput RTE	Yes	–
Non-RTE bandwidth	Yes	–
Time synchronization accuracy	Yes	–
Non-time-based synchronization accuracy	–	–
Redundancy recovery time	Yes	–

8.2.4.2 Performance indicator dependencies

8.2.4.2.1 Performance indicator dependency matrix

Table 62 specifies the dependencies of the performance indicators.

Table 62 – CP 3/4, CP 3/5 and CP 3/6: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchron. accuracy	Redundancy recovery time
Delivery time		Yes 8.2.4.2.4	NO	Yes 8.2.4.2.2	Yes 8.2.4.2.3	NO	NO	YES 8.2.4.2.5
Number of end-stations	YES 8.2.4.2.4		NO	NO	NO	NO	NO	NO
Basic network topology	YES 8.2.4.2.6	NO		NO	NO	NO	YES 8.2.4.2.7	YES 8.2.4.2.8
Number of switches between end-stations	YES 8.2.4.2.6	NO	NO		NO	NO	YES 8.2.4.2.7	YES 8.2.4.2.9
Throughput RTE	NO	NO	NO	NO		YES 8.2.4.2.10	NO	NO
Non-RTE bandwidth	NO	NO	NO	NO	YES 8.2.4.2.10		NO	NO
Time synchronization accuracy	NO	NO	NO	YES 8.2.4.2.11	NO	NO		NO
Redundancy recovery time	NO	NO	YES 8.2.4.2.8	YES 8.2.4.2.12	NO	NO	NO	

8.2.4.2.2 Delivery time

The performance indicator delivery time can be calculated by Formula (11).

$$DT = cta\_S + ctc + cta\_R + STTs + STTr + tt \times data + cd \times clt + \sum_{pd=1}^{NoS} f(pd) \times NoS + od \quad (11)$$

where

DT	is the Delivery time;
cta_R	is the application cycle time of the Receiver;
cta_S	is the application cycle time of the Sender;
ctc	is the communication cycle time (see Formula (12)) and shall be equal or longer than MinDeviceInterval;
STTs	is the sender stack traversal time;
STTr	is the receiver stack traversal time;
tt	is the transfer time (80 ns/octet for 100 Mbit/s, 8 ns/octet for 1 Gbit/s).
data	is the complete Ethernet frame;
cd	is the cable delay (see attribute CableDelayLocal in IEC 61158–5–10);
clt	is the total cable length;
pd	is the propagation delay (see Formula (13));
NoS	is the number of switches;
od	is any other delays, e. g. signal forwarding in a ring.

The communication cycle time can be calculated by Formula (12).

$$ctc = SCF \times RR \times 31{,}25 \mu s \quad (12)$$

where

SCF	is the attribute *SendClockFactor* (see IEC 61158–5–10, Send Clock Factor);
RR	is the attribute *ReductionRatio* (see IEC 61158–5–10, Reduction Ration).

The propagation delay pd can be calculated by Formula (13).

$$pd = Queue\_delay + Phy\_R\_delay + Phy\_S\_delay + MAC\_delay \quad (13)$$

where

Queue_delay	is the Queue delay in a switch;
Phy_R_delay	is the Phy delay on receiver side;
Phy_S_delay	is the Phy delay on sender side;
MAC_delay	is the delay on MAC layer.

Figure 5 represents the calculation basis for delivery time and throughput RTE and shows the logical position where some of the parameter occur.

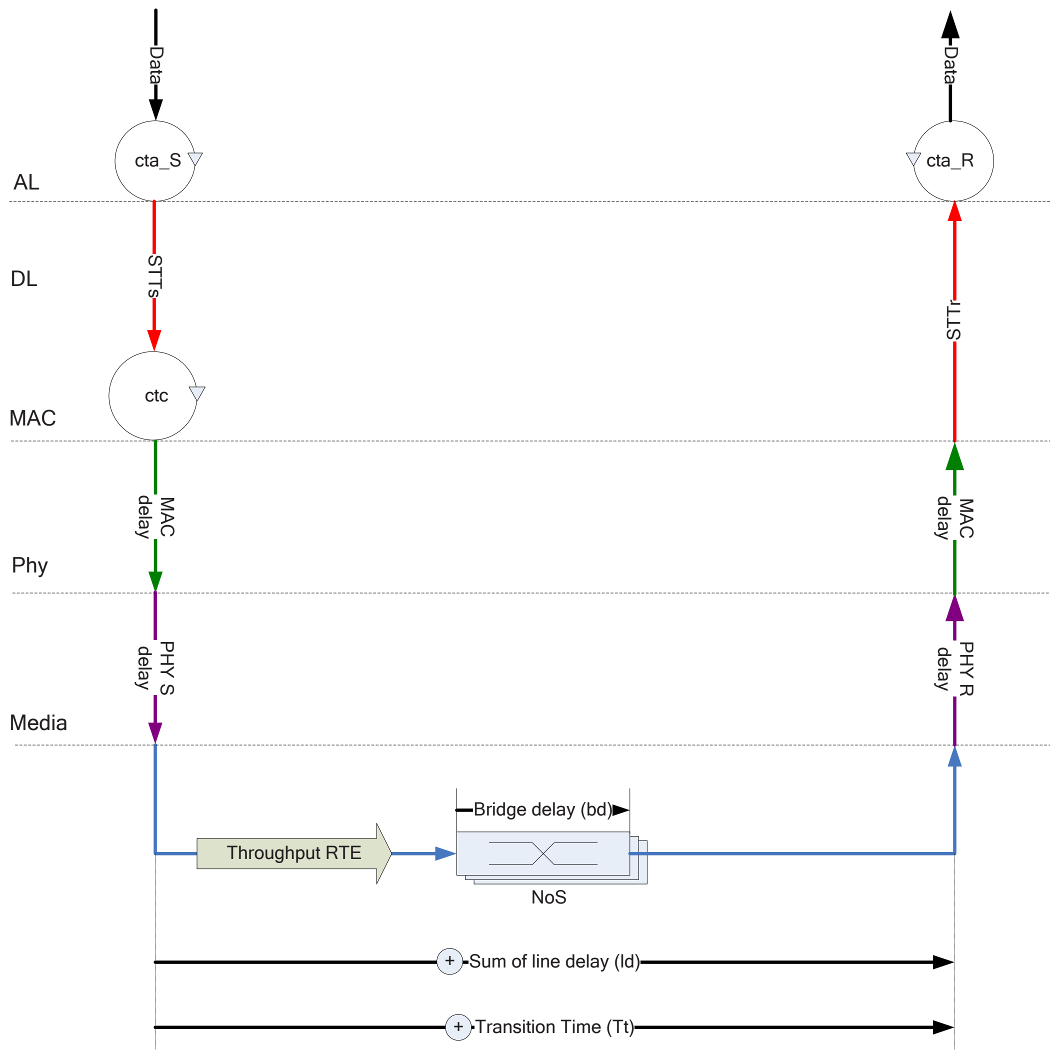

Figure 5 – Calculation basis for delivery time and throughput RTE

8.2.4.2.3 Delivery time dependency on throughput RTE

RTE throughput defines the amount of data within one ctc. Formula (14) specifies the dependencies to various parameters.

If data_request > data_RTE then (14)

- to enlarge throughput RTE
  - ctc constant as long as max throughput RTE could be enlarged to transmit data_request
  - enlarge ctc additionally as much as needed so that max throughput RTE could be enlarged to transmit data_request
- use of multiple ctc

where

data_request	is the requested throughput RTE;
data_RTE	is the actual throughput RTE,
ctc	is the communication cycle time (see Formula (12) in 8.2.4.2.2) and shall be equal or longer than MinDeviceInterval.

The parameter ctc and data are used in 8.2.4.2.2 to calculate delivery time.

8.2.4.2.4 Delivery time dependency on Number of end-stations

Number of end-stations influences the length of data within one ctc.

The parameter data is used in 8.2.4.2.2 to calculate Delivery time.

8.2.4.2.5 Delivery time dependency on Redundancy recovery time

NoS shall be set to the worst case value of all switches on the configured paths in a redundant topology.

The parameter NoS is used in 8.2.4.2.2 to calculate Delivery time.

8.2.4.2.6 Basic network topology dependency on Delivery time

If the delivery time in a daisy-chain or ring topology exceeds the bounded delivery time then the Basic network topology is to set to a hierarchical star.

8.2.4.2.7 Basic network topology dependency on Time synchron. accuracy

If the Time synchron. accuracy in a daisy-chain or ring topology exceeds the bounded Time synchron. accuracy then the Basic network topology is to set to a hierarchical star.

8.2.4.2.8 Basic network topology dependency on Redundancy recovery time

If redundancy recovery time allows use of rapid spanning tree algorithm and protocol (RSTP according to IEEE 802.1D) then no dependencies exist;

Redundancy recovery time of Media redundancy requires ring topology.

For RED_CLASS_1 and RED_CLASS_3, ring ports shall comply to Media Class wired and fiber optic according to 8.2.1.1. The data rate of both ring ports shall be at least 100 Mbit/s and full duplex mode shall be used for both ring ports.

For RED_CLASS_1 the redundancy manager defines with its parameter set the recovery time of a ring. Table 63 specifies the consistent set of parameter for a ring recovery time of 200 ms.

The traffic load in the ring shall be less than 90 %.

Table 63 – Manager parameters

Parameter	Value	Comment
MRP_TOPchgT	10 ms	IEC 61158–6–10
MRP_TOPNRmax	3	IEC 61158–6–10
MRP_TSTshortT	10 ms	IEC 61158–6–10
MRP_TSTdefaultT	20 ms	IEC 61158–6–10
MRP_TSTNRmax	3	IEC 61158–6–10

For RED_CLASS_1 and RED_CLASS_3, Table 64 specifies the parameter set for media redundancy clients.

Table 64 – Client parameters

Parameter	Value	Comment
MRP_LNKdownT	20 ms	IEC 61158–6–10
MRP_LNKupT	20 ms	IEC 61158–6–10
MRP_LNKNRmax	4	IEC 61158–6–10

8.2.4.2.9 NoS dependency on Redundancy recovery time

The time to detect the failure is dependent from the NoS.

8.2.4.2.10 Throughput RTE dependency on non-RTE bandwidth

The throughput RTE can be calculated by Formula (15).

$$Throughput\_RTE = (100\% - NonRTE - protocolRTE) * EthernetDataRate / 8 \qquad (15)$$

where

Throughput_RTE is the throughput RTE in octets/s;
protocolRTE is the percentage of protocol time, see Formula (16);
NonRTE is the percentage of non-RTE bandwidth;
EthernetDataRate is the Ethernet data rate of the network.

The protocolRTE can be calculated by Formula (16).

$$protocolRTE = f_{complex}(\mathrm{endStations, data, Time\_synchron\_accuracy, RM, ...}) \qquad (16)$$

where

endStations is the number of end-stations;
data is the complete Ethernet frame in octets;
Time_synchron_accuracy is the time synchronization accuracy;
RM is the time needed for management functions to support redundancy.

8.2.4.2.11 Time synchron. accuracy dependency on NoS

Time synchron. accuracy using up to 20 NoS.

8.2.4.2.12 Redundancy recovery time dependency on NoS

The time to detect the failure is dependent from the NoS.

8.2.4.3 Consistent set of performance indicators

Table 65 specifies the consistent set of performance indicators using a network bandwidth of 100 Mbit/s, wired or fiber optic. The values are based of the values given in Table 66 and the methods or algorithm given in 8.2.4.2. This consistent set of performance indicators shall be tested for devices (not wireless) that claim compliance with CP 3/4.

Table 65 – CP 3/4: Consistent set of PIs for MinDeviceInterval=128 ms

Performance indicator	Value	Constraints
Delivery time	128 ms watch dog factor × 128 ms	Without failure Frames lost; (See 8.1, MinDeviceInterval = 128 ms)
Number of end-stations	60	Data is assumed to be a 68 octets Ethernet frame to receive from and send to all end-stations
Number of switches between end-stations	10	–
Throughput RTE	2 324 706 octet/s	–
Non-RTE bandwidth	23,5 %	100 Mbit/s and related to 1 ms. Any IEEE 802.3 frames supported.
Time synchronization accuracy [c]	< 1 ms	Synchronization of local time
	< 1 µs	Synchronization of synchronous application
Redundancy recovery time [c]	0 ms < 200 ms	RT_CLASS_1 [a]: single failure RTA[b] retries = 3; RTA timeout factor = 100 ms
	< 384 ms < 200 ms	RT_CLASS_1 [a]: double failure (line break and surge) watch dog factor = 3; delivery time = 128 ms RTA [b] retries = 3; RTA [b] timeout factor = 100 ms

[a] The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.

[b] The attributes RTA Retries and RTA Timeout Factor are specified in 8.3.10.4.2 of IEC 61158–5–10.

[c] Optional

Table 66 – CP 3/4: Assumed values for consistent set of PI calculation

Symbol	Definition	Value
cd	is the cable delay (see parameter cable_delay in IEC 61158–6–10)	5 ns
clt	is the total cable length	100 m
cta_R	is the application cycle time of the Receiver	1 µs
cta_S	is the application cycle time of the Sender	1 µs
ctc	is the communication cycle time (see Formula (12) in 8.2.4.2.2) and shall be equal or longer than MinDeviceInterval = 128 ms	128 ms
data	is the complete Ethernet frame	68 octets
EthernetDataRate	is the Ethernet data rate of the network	Mbit/s
MAC_delay	is the delay on MAC layer	1 µs
NonRTE	is the percentage of non-RTE bandwidth	%
od	is any other delays, e. g. signal forwarding in a ring	0 s
pd	is the propagation delay (see Formula (13) in 8.2.4.2.2)	–
Phy_R_delay	is the Phy delay on receiver side	300 ns
Phy_S_delay	is the Phy delay on sender side	300 ns
protocolRTE	is the percentage of protocol time (see Formula (16) in 8.2.4.2.10)	50 %
Queue_delay	is the Queue delay in a switch	0 s
RedundancyManagement	is the time needed for management functions to support redundancy	0 s

Symbol	Definition	Value
STTr	is the receiver stack traversal time	0 s
STTs	is the sender stack traversal time	0 s
Time_synchron_accuracy	is the time synchronization accuracy	0 s
tt	is the transfer time (80 ns/octet for 100 Mbit/s, 8 ns/octet for 1 Gbit/s)	80 ns
SCF	See IEC 61158–5–10, 8.3.10.4.2	32
RR	See IEC 61158–5–10, 8.3.10.4.2	128

8.3 Profile 3/5

8.3.1 Physical layer

The physical layer shall be according to IEEE 802.3.

The data rate shall be at least 100 Mbit/s and full-duplex mode shall be used at least for one port.

Devices shall comply with the legal requirements of that country where they are deployed (for example, as indicated by the CE mark). The measures for protection against electrical shocks (i.e. electrical safety) within industrial applications shall be based on the IEC 61010 series or IEC 61131-2 depending on device type specified therein.

8.3.2 Data link layer

The data link layer shall be according to IEEE 802.3, IEEE 802.1AB, IEEE 802.1D, and IEEE 802.1Q.

From the various optional Management Information Bases (MIBs) at least the LLDP MIB (see IEEE 802.1AB) and SNMP MIB-II (see RFC 1213) are required.

It is recommended to limit the local injected non real time traffic of each node to 3 Koctets per millisecond to avoid a network overload.

8.3.3 Application layer

8.3.3.1 AL service selection

8.3.3.1.1 IO device

Application layer services for an IO device are defined in IEC 61158–5–10. Table 67 holds the application layer service selections from IEC 61158–5–10 for this profile.

Table 67 – CP 3/5: AL service selection for an IO device

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Concepts	YES	–
5	Data type ASE	YES	–
6	Communication model for common services	–	–
6.1	Concepts	YES	–
6.2	ASE data types	YES	–
6.3	ASEs	–	–
6.3.1	Discovery and basic configuration ASE	YES	–
6.3.2	Precision time control ASE	YES	Optional
6.3.3	Media redundancy ASE	YES	See 8.1.6, n.a. for wireless media
6.3.4	Real-time cyclic ASE	YES	RT_CLASS_UDP is optional
6.3.5	Real-time acyclic ASE	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.6	Remote procedure call ASE	YES	–
6.3.7	IEEE 802.1AB ASE	YES	n.a. for wireless media
6.3.8	IEEE 802.1AS ASE	YES	Optional
6.3.9	IEEE 802.1D ASE	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
6.3.10	IEEE 802.1Q ASE	YES	n.a. for wireless media
6.3.11	IEEE 802.3 ASE	YES	n.a. for wireless media
6.3.12	Fragmentation ASE	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
6.3.13	IP suite ASE	YES	ICMP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.14	Domain name system ASE	YES	Optional
6.3.15	Dynamic host configuration ASE	YES	Optional
6.3.16	Simple network management ASE	YES	–
6.3.17	Common DL Mapping ASE	–	–
6.3.17.1	Overview	YES	–
6.3.17.2	DL Mapping class specification	YES	–
6.3.17.3	DL Mapping service specification	–	–
6.3.17.3.1	P Data	YES	Optional; mandatory if Precision Time Control ASE is supported
6.3.17.3.2	N Data	YES	–
6.3.17.3.3	A Data	YES	–
6.3.17.3.4	C Data	YES	–
7	Communication model for decentralized periphery	–	–
7.1	Concepts	YES	–
7.2	ASE data types	YES	–
7.3	ASEs	–	–
7.3.1	Record Data ASE	YES	–
7.3.2	IO Data ASE	YES	–
7.3.3	LogBook Data ASE	YES	–
7.3.4	Diagnosis ASE	YES	–

Clause	Header	Presence	Constraints
7.3.5	Alarm ASE	YES	–
7.3.6	Context ASE	YES	–
7.3.7	Isochronous Mode Application ASE	NO	–
7.3.8	Physical Device Management ASE	YES	–
7.3.9	AR ASE	YES	–
7.4	Behavior of an IO device	–	–
7.4.1	Overview	YES	–
7.4.2	Startup of an IO device	YES	–
7.4.3	Physical device parameter check	–	–
7.4.3.1	General	YES	–
7.4.3.2	Remote system data	YES	–
7.4.3.3	Local system data	YES	–
7.4.3.4	Optical system data	YES	Optional; mandatory if fiber optic is used
7.4.4	Diagnosis and problem indicator	YES	–
7.4.5	User alarms	YES	–
7.4.6	Behavior in case of configuration change	YES	–
7.4.7	Behavior for PTCP within IO devices	YES	Optional; mandatory if precision time control ASE (see 6.3.2) is supported
7.5	Behavior of an IO controller	NO	–
7.6	Application characteristics	YES	–
Annex A	Device instances	YES	–
Annex B	Components of an Ethernet interface	Partial	Used when applicable
Annex C	Scheme of MAC address assignment	YES	–
Annex D	Collection of objects	YES	–
Annex E	Measurement of the fast startup time	YES	–
Annex F	Dynamic Frame Packing	YES	Optional
Annex G	Building IR Data	YES	Optional; mandatory if RT_CLASS_3 is used

8.3.3.1.2 Network component

Application layer services for a network component are defined in IEC 61158–5–10. Table 67 holds the application layer service selections from IEC 61158–5–10 for this profile.

A 100 Mbit/s switch should support a buffering of all data of at least 1 ms. This should be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

A 100 Mbit/s switch with less than eight ports shall provide buffering capacity according to Table 69, with eight and more ports according to Table 70. This shall be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

8.3.3.1.3 IO controller

Application layer services for an IO controller are defined in IEC 61158–5–10. Table 67 holds the application layer service selections from IEC 61158–5–10 for this profile except 7.4 is NO and 7.5 is YES.

8.3.3.1.4 IO supervisor

See 8.4.3.1.3.

8.3.3.1.5 Options

DHCP according to RFC 2131 is an optional service.

DNS is an optional service for an IO controller and IO supervisor.

MRP is an optional service.

PTCP is an optional service.

8.3.3.2 AL protocol selection

8.3.3.2.1 IO device

Application layer protocols for an IO device are defined in IEC 61158–6–10. Table 68 holds the application layer protocol selections from IEC 61158–6–10 for this profile.

Table 68 – CP 3/5: AL protocol selection for an IO device and Network component

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Application Layer protocol specification for common protocols	–	–
4.1	FAL syntax description	YES	–
4.2	Transfer syntax	–	–
4.2.1	Coding of basic data types	Partial	Used as needed
4.2.2	Coding section related to common basic fields	Partial	Used as needed
4.3	Discovery and basic configuration	YES	–
4.4	Precision working time control	YES	Optional, n.a. for wireless media
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real-time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real-time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
4.10	Remote procedure call	YES	–
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	MAC bridges	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
4.13	Virtual bridges	YES	n.a. for wireless
4.14	IP suite	YES	–
4.15	Domain name system	YES	Optional
4.16	Dynamic host configuration	YES	Optional
4.17	Simple network management	YES	–
4.18	Common DLL Mapping Protocol Machines	YES	–
5	Application Layer protocol specification for decentralized periphery	–	–

Clause	Header	Presence	Constraints
5.1	FAL syntax description	YES	–
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	–
5.5	FAL Service Protocol Machines	–	–
5.5.1	Overview	YES	–
5.5.2	FAL Service Protocol Machine Device	YES	–
5.5.3	FAL Service Protocol Machine Controller	NO	–
5.6	Application Relationship Protocol Machines	–	–
5.6.1	Alarm Protocol Machine Initiator	YES	–
5.6.2	Alarm Protocol Machine Responder	YES	–
5.6.3	Device	YES	–
5.6.4	Controller	NO	–
5.7	DLL Mapping Protocol Machines	YES	–
Annex A	Unified establishing of an AR for all RT classes	YES	–
Annex B	Compatible establishing of an AR	YES	–
Annex C	Establishing of a device access AR	YES	–
Annex D	Establishing of an AR (accelerated procedure)	YES	–
Annex E	Establishing of an AR (fast startup procedure)	YES	–
Annex F	Example of the upload, storage and retrieval procedure	YES	–
Annex G	OSI reference model layers	YES	–
Annex H	Overview of the IO controller and the IO device state machines	YES	–
Annex I	Priority regeneration	YES	–
Annex J	Overview of the synchronization master hierarchy	YES	Optional; mandatory if Precision time control is supported
Annex K	Optimization of bandwith usage	YES	–
Annex L	Time constraints for bandwidth allocation	YES	Optional; mandatory if RT_CLASS_2 or RT_CLASS_3 are supported
Annex M	Time constraints for the forwarding of a frame	YES	–
Annex N	Principle of dynamic frame packing	YES	Optional
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	–
Annex S	TX-error handling	YES	–
Annex T	Example of a PrmBegin, PrmEnd and ApplRdy procedure	YES	–
Annex U	List of supported MIBs	YES	–
Annex V	Structure and content of BLOB	YES	If needed
Annex W	LLDP EXT MIB	YES	–

8.3.3.2.2 Network component

Application layer protocols for a network component are defined in IEC 61158–6–10. Table 68 specifies the clauses included in this profile.

A 100 Mbit/s switch should support a buffering of all data of at least 1 ms. This should be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

A 100 Mbit/s switch with less than eight ports shall provide buffering capacity according to Table 69, with eight and more ports according to Table 70. This shall be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

Table 69 – Buffering capacity for less than eight ports

Meaning	Value
Buffering capacity per port	10 Koctets

Table 70 – Buffering capacity for eight and more ports

Meaning	Value
Buffering capacity	80 Koctets

8.3.3.2.3 IO controller

Application layer protocols for an IO controller are defined in IEC 61158–6–10. Table 71 specifies the clauses included in this profile.

Table 71 – CP 3/5: AL protocol selection for an IO controller

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Application Layer protocol specification for common protocols	–	–
4.1	FAL syntax description	YES	–
4.2	Transfer syntax	–	–
4.2.1	Coding of basic data types	Partial	Used as needed
4.2.2	Coding section related to common basic fields	Partial	Used as needed
4.3	Discovery and basic configuration	YES	–
4.4	Precision working time control	YES	Optional, n.a. for wireless media
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real-time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real-time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
4.10	Remote procedure call	YES	–
4.11	Link layer discovery	YES	n.a. for wireless media

Clause	Header	Presence	Constraints
4.12	MAC bridges	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
4.13	Virtual bridges	YES	n.a. for wireless
4.14	IP suite	YES	–
4.15	Domain name system	YES	Optional
4.16	Dynamic host configuration	YES	Optional
4.17	Simple network management	YES	–
4.18	Common DLL Mapping Protocol Machines	YES	–
5	Application Layer protocol specification for decentralized periphery	–	–
5.1	FAL syntax description	YES	–
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	–
5.5	FAL Service Protocol Machines	–	–
5.5.1	Overview	YES	–
5.5.2	FAL Service Protocol Machine Device	NO	–
5.5.3	FAL Service Protocol Machine Controller	YES	–
5.6	Application Relationship Protocol Machines	–	–
5.6.1	Alarm Protocol Machine Initiator	YES	–
5.6.2	Alarm Protocol Machine Responder	YES	–
5.6.3	Device	NO	–
5.6.4	Controller	YES	–
5.7	DLL Mapping Protocol Machines	YES	–
Annex A	Unified establishing of an AR for all RT classes	YES	–
Annex B	Compatible establishing of an AR	YES	–
Annex C	Establishing of a device access AR	YES	–
Annex D	Establishing of an AR (accelerated procedure)	YES	–
Annex E	Establishing of an AR (fast startup procedure)	YES	–
Annex F	Example of the upload, storage and retrieval procedure	YES	–
Annex G	OSI reference model layers	YES	–
Annex H	Overview of the IO controller and the IO device state machines	YES	–
Annex I	Priority regeneration	YES	–
Annex J	Overview of the synchronization master hierarchy	YES	Optional; mandatory if Precision time control is supported
Annex K	Optimization of bandwith usage	YES	–
Annex L	Time constraints for bandwidth allocation	YES	Optional; mandatory if RT_CLASS_3 is supported
Annex M	Time constraints for the forwarding of a frame	YES	–
Annex N	Principle of dynamic frame packing	YES	Optional
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.

Clause	Header	Presence	Constraints
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	–
Annex S	TX-error handling	YES	–
Annex T	Example of a PrmBegin, PrmEnd and ApplRdy procedure	YES	–
Annex U	List of supported MIBs	YES	–
Annex V	Structure and content of BLOB	YES	If needed
Annex W	LLDP EXT MIB	YES	–

8.3.3.2.4 IO supervisor

See 8.2.3.1.3.

8.3.3.2.5 Options

DHCP according to RFC 2131 is an optional protocol.

DNS is an optional protocol for an IO controller and IO supervisor.

Media redundancy (see 8.1.6).

PTCP is an optional service.

8.3.4 Performance indicator selection

8.3.4.1 Performance indicator overview

Subclause 8.2.4.1 applies.

8.3.4.2 Performance indicator dependencies

Subclause 8.2.4.2 applies.

8.3.4.3 Consistent set of performance indicators

Table 72 specifies the consistent set of performance indicators using a network bandwidth of 100 Mbit/s, wired or fiber optic. The values are based of the values given in Table 73 and the methods or algorithm given in 8.2.4.2. This consistent set of performance indicators shall be tested for devices (not for wireless) that claim compliance with CP 3/5.

Table 72 – CP 3/5: Consistent set of PIs for MinDeviceInterval=128 ms

Performance indicator	Value	Constraints
Delivery time	128 ms watch dog factor × 128 ms	Without failure Frames lost; (See 8.1, MinDeviceInterval = 128 ms)
Number of end-stations	60	Data is assumed to be a 68 octets Ethernet frame to receive from and send to all end-stations
Number of switches between end-stations	10	–
Throughput RTE	2 324 706 octet/s	–
Non-RTE bandwidth	23,5 %	100 Mbit/s and related to 1 ms. Any IEEE 802.3 frames supported.
Time synchronization accuracy[c]	< 1 ms	Synchronization of local time
	< 1 µs	Synchronization of synchronous application
Redundancy recovery time[c]	0 ms < 200 ms	RT_CLASS_1 [a]: single failure RTA [b] retries = 3; RTA timeout factor = 100 ms
	< 384 ms < 200 ms	RT_CLASS_1 [a]: double failure (line break and surge) watch dog factor = 3; delivery time = 128 ms RTA [b] retries = 3; RTA [b] timeout factor = 100 ms

[a] The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.

[b] The attributes RTA Retries and RTA Timeout Factor are specified in 8.3.10.4.2 of IEC 61158–5–10.

[c] Optional

Table 73 – CP 3/5: Assumed values for consistent set of PI calculation

Symbol	Definition	Value
cd	is the cable delay (see parameter cable_delay in IEC 61158–6–10)	5 ns
clt	is the total cable length	100 m
cta_R	is the application cycle time of the Receiver	1 µs
cta_S	is the application cycle time of the Sender	1 µs
ctc	is the communication cycle time (see Formula (12) in 8.2.4.2.2) and shall be equal or longer than MinDeviceInterval = 128 ms	128 ms
data	is the complete Ethernet frame	68 octets
EthernetDataRate	is the Ethernet data rate of the network	Mbit/s
MAC_delay	is the delay on MAC layer	1 µs
NonRTE	is the percentage of non-RTE bandwidth	%
od	is any other delays, e. g. signal forwarding in a ring	0 s
pd	is the propagation delay (see Formula (13) in 8.2.4.2.2)	–
Phy_R_delay	is the Phy delay on receiver side	300 ns
Phy_S_delay	is the Phy delay on sender side	300 ns
protocolRTE	is the percentage of protocol time (see Formula (16) in 8.2.4.2.10)	50 %
Queue_delay	is the Queue delay in a switch	0 s
RedundancyManagement	is the time needed for management functions to support redundancy	0 s
STTr	is the receiver stack traversal time	0 s

Symbol	Definition	Value
STTs	is the sender stack traversal time	0 s
Time_synchron_accuracy	is the time synchronization accuracy	0 s
tt	is the transfer time (80 ns/octet for 100 Mbit/s, 8 ns/octet for 1 Gbit/s)	80 ns
SCF	See IEC 61158–5–10, 8.3.10.4.2	32
RR	See IEC 61158–5–10, 8.3.10.4.2	128

8.4 Profile 3/6

8.4.1 Physical layer

The physical layer shall be according to IEEE 802.3.

The data rate shall be at least 100 Mbit/s and full-duplex mode shall be used at least for one port.

Devices shall comply with the legal requirements of that country where they are deployed (for example, as indicated by the CE mark). The measures for protection against electrical shocks (i.e. electrical safety) within industrial applications shall be based on the IEC 61010 series or IEC 61131–2 depending on device type specified therein.

8.4.2 Data link layer

The data link layer shall be according to IEEE 802.3, IEEE 802.1AB, IEEE 802.1D, and IEEE 802.1Q.

From the various optional Management Information Bases (MIBs) at least the LLDP MIB (see IEEE 802.1AB) and SNMP MIB-II (see RFC 1213) are required.

It is recommended to limit the local injected non real time traffic of each node to 3 Koctets per millisecond to avoid a network overload.

8.4.3 Application layer

8.4.3.1 AL service selection

8.4.3.1.1 IO device

Application layer services for an IO device are defined in IEC 61158–5–10. Table 74 holds the application layer service selections from IEC 61158–5–10 for this profile.

Table 74 – CP 3/6: AL service selection for an IO device

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Concepts	YES	–
5	Data type ASE	YES	–
6	Communication model for common services	–	–
6.1	Concepts	YES	–
6.2	ASE data types	YES	–
6.3	ASEs	–	–
6.3.1	Discovery and basic configuration ASE	YES	–
6.3.2	Precision time control ASE	YES	Optional
6.3.3	Media redundancy ASE	YES	See 8.1.6, n.a. for wireless media
6.3.4	Real-time cyclic ASE	YES	RT_CLASS_UDP is optional
6.3.5	Real-time acyclic ASE	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.6	Remote procedure call ASE	YES	–
6.3.7	IEEE 802.1AB ASE	YES	n.a. for wireless media
6.3.8	IEEE 802.1AS ASE	YES	Optional
6.3.9	IEEE 802.1D ASE	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
6.3.10	IEEE 802.1Q ASE	YES	n.a. for wireless media
6.3.11	IEEE 802.3 ASE	YES	n.a. for wireless media
6.3.12	Fragmentation ASE	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
6.3.13	IP suite ASE	YES	ICMP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.14	Domain name system ASE	YES	Optional
6.3.15	Dynamic host configuration ASE	YES	Optional
6.3.16	Simple network management ASE	YES	–
6.3.17	Common DL Mapping ASE	–	–
6.3.17.1	Overview	YES	–
6.3.17.2	DL Mapping class specification	YES	–
6.3.17.3	DL Mapping service specification	–	–
6.3.17.3.1	P Data	YES	–
6.3.17.3.2	N Data	YES	–
6.3.17.3.3	A Data	YES	–
6.3.17.3.4	C Data	YES	–
7	Communication model for decentralized periphery	–	–
7.1	Concepts	YES	–
7.2	ASE data types	YES	–

Clause	Header	Presence	Constraints
7.3	ASEs	–	–
7.3.1	Record Data ASE	YES	–
7.3.2	IO Data ASE	YES	–
7.3.3	LogBook Data ASE	YES	–
7.3.4	Diagnosis ASE	YES	–
7.3.5	Alarm ASE	YES	–
7.3.6	Context ASE	YES	–
7.3.7	Isochronous Mode Application ASE	NO	–
7.3.8	Physical Device Management ASE	YES	–
7.3.9	AR ASE	YES	–
7.4	Behavior of an IO device	–	–
7.4.1	Overview	YES	–
7.4.2	Startup of an IO device	YES	–
7.4.3	Physical device parameter check	–	–
7.4.3.1	General	YES	–
7.4.3.2	Remote system data	YES	–
7.4.3.3	Local system data	YES	–
7.4.3.4	Optical system data	YES	Optional; mandatory if fiber optic is used
7.4.4	Diagnosis and problem indicator	YES	–
7.4.5	User alarms	YES	–
7.4.6	Behavior in case of configuration change	YES	–
7.4.7	Behavior for PTCP within IO devices	YES	–
7.5	Behavior of an IO controller	NO	–
7.6	Application characteristics	YES	–
Annex A	Device instances	YES	–
Annex B	Components of an Ethernet interface	Partial	Used when applicable
Annex C	Scheme of MAC address assignment	YES	–
Annex D	Collection of objects	YES	–
Annex E	Measurement of the fast startup time	YES	–
Annex F	Dynamic Frame Packing	YES	Optional
Annex G	Building IR Data	YES	–

8.4.3.1.2 Network component

Application layer services for a network component are defined in IEC 61158–5–10. Table 74 holds the application layer service selections from IEC 61158–5–10 for this profile.

A 100 Mbit/s switch shall support buffering of all data according to Table 75. This shall be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

Table 75 – Buffering capacity

Meaning	Value	
Buffering capacity	Recommended:	1 ms
	Mandatory:	500 µs

8.4.3.1.3 IO controller

Application layer services for an IO controller are defined in IEC 61158–5–10. Table 74 holds the application layer service selections from IEC 61158–5–10 for this profile except 7.4 is NO and 7.5 is YES.

8.4.3.1.4 IO supervisor

Not applicable.

8.4.3.1.5 Options

DHCP according to RFC 2131 is an optional service.

DNS is an optional service for an IO controller and IO supervisor.

8.4.3.2 AL protocol selection

8.4.3.2.1 IO device

Application layer protocols for an IO device are defined in IEC 61158–6–10. Table 76 holds the application layer protocol selections from IEC 61158–6–10 for this profile.

Table 76 – CP 3/6: AL protocol selection for an IO device and network component

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Application Layer protocol specification for common protocols	–	–
4.1	FAL syntax description	YES	–
4.2	Transfer syntax	–	–
4.2.1	Coding of basic data types	Partial	Used as needed
4.2.2	Coding section related to common basic fields	Partial	Used as needed
4.3	Discovery and basic configuration	YES	–
4.4	Precision working time control	YES	–
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real-time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real-time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.

Clause	Header	Presence	Constraints
4.10	Remote procedure call	YES	–
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	MAC bridges	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
4.13	Virtual bridges	YES	n.a. for wireless media
4.14	IP suite	YES	–
4.15	Domain name system	YES	Optional
4.16	Dynamic host configuration	YES	Optional
4.17	Simple network management	YES	–
4.18	Common DLL Mapping Protocol Machines	YES	–
5	Application Layer protocol specification for decentralized periphery	–	–
5.1	FAL syntax description	YES	–
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	–
5.5	FAL Service Protocol Machines	–	–
5.5.1	Overview	YES	–
5.5.2	FAL Service Protocol Machine Device	YES	–
5.5.3	FAL Service Protocol Machine Controller	NO	–
5.6	Application Relationship Protocol Machines	–	–
5.6.1	Alarm Protocol Machine Initiator	YES	–
5.6.2	Alarm Protocol Machine Responder	YES	–
5.6.3	Device	YES	–
5.6.4	Controller	NO	–
5.7	DLL Mapping Protocol Machines	YES	–
Annex A	Unified establishing of an AR for all RT classes	YES	–
Annex B	Compatible establishing of an AR	YES	–
Annex C	Establishing of a device access AR	YES	–
Annex D	Establishing of an AR (accelerated procedure)	YES	–
Annex E	Establishing of an AR (fast startup procedure)	YES	–
Annex F	Example of the upload, storage and retrieval procedure	YES	–
Annex G	OSI reference model layers	YES	–
Annex H	Overview of the IO controller and the IO device state machines	YES	–
Annex I	Priority regeneration	YES	–
Annex J	Overview of the synchronization master hierarchy	YES	–
Annex K	Optimization of bandwith usage	YES	–
Annex L	Time constraints for bandwidth allocation	YES	–
Annex M	Time constraints for the forwarding of a frame	YES	–
Annex N	Principle of dynamic frame packing	YES	Optional

Clause	Header	Presence	Constraints
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 μs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	–
Annex S	TX-error handling	YES	–
Annex T	Example of a PrmBegin, PrmEnd and ApplRdy procedure	YES	–
Annex U	List of supported MIBs	YES	–
Annex V	Structure and content of BLOB	YES	If needed
Annex W	LLDP EXT MIB	YES	–

8.4.3.2.2 Network component

Application layer protocols for a network component are defined in IEC 61158–6–10. Table 76 specifies the clauses included in this profile.

A 100 Mbit/s switch shall support buffering of all data according to Table 75. This shall be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

8.4.3.2.3 IO controller

Application layer protocols for an IO controller are defined in IEC 61158–6–10. Table 77 specifies the clauses included in this profile.

Table 77 – CP 3/6: AL protocol selection for an IO controller

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Application Layer protocol specification for common protocols	–	–
4.1	FAL syntax description	YES	–
4.2	Transfer syntax	–	–
4.2.1	Coding of basic data types	Partial	Used as needed
4.2.2	Coding section related to common basic fields	Partial	Used as needed
4.3	Discovery and basic configuration	YES	–
4.4	Precision working time control	YES	n.a. for wireless media
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real-time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real-time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 μs are supported.

Clause	Header	Presence	Constraints
4.10	Remote procedure call	YES	–
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	MAC bridges	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
4.13	Virtual bridges	YES	n.a. for wireless media
4.14	IP suite	YES	–
4.15	Domain name system	YES	Optional
4.16	Dynamic host configuration	YES	Optional
4.17	Simple network management	YES	–
4.18	Common DLL Mapping Protocol Machines	YES	–
5	Application Layer protocol specification for decentralized periphery	–	–
5.1	FAL syntax description	YES	–
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	–
5.5	FAL Service Protocol Machines	–	–
5.5.1	Overview	YES	–
5.5.2	FAL Service Protocol Machine Device	NO	–
5.5.3	FAL Service Protocol Machine Controller	YES	–
5.6	Application Relationship Protocol Machines	–	–
5.6.1	Alarm Protocol Machine Initiator	YES	–
5.6.2	Alarm Protocol Machine Responder	YES	–
5.6.3	Device	NO	–
5.6.4	Controller	YES	–
5.7	DLL Mapping Protocol Machines	YES	–
Annex A	Unified establishing of an AR for all RT classes	YES	–
Annex B	Compatible establishing of an AR	YES	–
Annex C	Establishing of a device access AR	YES	–
Annex D	Establishing of an AR (accelerated procedure)	YES	–
Annex E	Establishing of an AR (fast startup procedure)	YES	–
Annex F	Example of the upload, storage and retrieval procedure	YES	–
Annex G	OSI reference model layers	YES	–
Annex H	Overview of the IO controller and the IO device state machines	YES	–
Annex I	Priority regeneration	YES	–
Annex J	Overview of the synchronization master hierarchy	YES	–
Annex K	Optimization of bandwith usage	YES	–
Annex L	Time constraints for bandwidth allocation	YES	–
Annex M	Time constraints for the forwarding of a frame	YES	–
Annex N	Principle of dynamic frame packing	YES	Optional
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	–

Clause	Header	Presence	Constraints
Annex S	TX-error handling	YES	–
Annex T	Example of a PrmBegin, PrmEnd and ApplRdy procedure	YES	–
Annex U	List of supported MIBs	YES	–
Annex V	Structure and content of BLOB	YES	If needed
Annex W	LLDP EXT MIB	YES	–

8.4.3.2.4 IO supervisor

Not applicable.

8.4.3.2.5 Options

Subclause 8.4.3.1.5 applies.

8.4.4 Performance indicator selection

8.4.4.1 Performance indicator overview

Subclause 8.2.4.1 applies.

8.4.4.2 Performance indicator dependencies

Subclause 8.2.4.2 applies.

8.4.4.3 Consistent set of performance indicators

8.4.4.3.1 MinDeviceInterval=1 ms

Table 78 and Table 79 specifies the consistent set of performance indicators using a network bandwidth of 100 Mbit/s, wired or fiber optic. The values are based of the figures given in Table 80 and the methods or algorithm given in 8.2.4.2. This consistent set of performance indicators shall be tested for devices (not wireless) that claim compliance with CP 3/6.

Table 78 – CP 3/6: Consistent set of PIs for MinDeviceInterval=1 ms and NumberOfSwitches=20

Performance indicator	Value	Constraints
Delivery time	1 ms watch dog factor × 1 ms	Without failure Frames lost; (See 8.1, MinDeviceInterval = 1 ms)
Number of end-stations	60	Using 4 port switches and line topology; a switch is also an end-station
Number of switches between end-stations	20	–
Throughput RTE	3 324 706 octets/s	–
Non-RTE bandwidth	23,5 %	100 Mbit/s and related to 1 ms. Any IEEE 802.3 frames supported.
Time synchronization accuracy	< 1 ms	Synchronization of local time [c]
	< 1 µs	Synchronization of synchronous application
Redundancy recovery time	<0 ms < 200 ms	RT_CLASS_3 [a]: single failure RTA [b] retries = 3; RTA timeout factor = 100 ms
	< 3 ms < 200 ms	RT_CLASS_3 [a]: double failure (line break and surge) watch dog factor = 3; delivery time = 1 ms RTA [b] retry = 3; RTA time out factor = 100 ms

[a] The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.

[b] The attributes RTA Retries and RTA Timeout Factor are specified in 8.3.10.4 of IEC 61158–5–10.

[c] Optional.

Table 79 – CP 3/6: Consistent set of PI for MinDeviceInterval=1 ms and NumberOfSwitches=63

Performance indicator	Value	Constraints
Delivery time	1 ms watch dog factor × 1 ms	Without failure Frames lost; (See 8.1, MinDeviceInterval = 1 ms)
Number of end-stations	64	Using 2 port switches and line topology; a switch is also an end-station
Number of switches between end-stations	62	–
Throughput RTE	3 546 353 octets/s	–
Non-RTE bandwidth	23 %	100 Mbit/s and related to 1 ms. Any IEEE 802.3 frames supported.
Time synchronization accuracy	< 1 ms	Synchronization of local time [c]
	< 1 µs	Synchronization of synchronous application
Redundancy recovery time	<0 ms < 200 ms	RT_CLASS_3 [a]: single failure RTA[b] retries = 3; RTA timeout factor = 100 ms
	< 3 ms < 200 ms	RT_CLASS_3 [a]: double failure (line break and surge) watch dog factor = 3; delivery time = 1 ms RTA [b] retry = 3; RTA time out factor = 100 ms

[a] The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.

[b] The attributes RTA Retries and RTA Timeout Factor are specified in 8.3.10.4 of IEC 61158–5–10.

[c] Optional.

Table 80 – CP 3/6: Assumed values for consistent set of PI calculation

Symbol	Definition	Value
Cd	is the cable delay (see parameter cable_delay in IEC 61158–6–10)	5 ns
Clt	is the total cable length	100 m
cta_R	is the application cycle time of the Receiver	1 µs
cta_S	is the application cycle time of the Sender	1 µs
Ctc	is the communication cycle time (see Formula (12) in 8.2.4.2.2) and shall be equal or longer than MinDeviceInterval	1 ms
Data	is the complete Ethernet frame	68 octets
EthernetDataRate	is the Ethernet data rate of the network	Mbit/s
MAC_delay	is the delay on MAC layer	1 µs
NonRTE	is the percentage of non-RTE bandwidth	%
Od	is any other delays, e. g. signal forwarding in a ring	0 s
Pd	is the propagation delay (see Formula (13) in 8.2.4.2.2)	–
Phy_R_delay	is the Phy delay on receiver side	300 ns
Phy_S_delay	is the Phy delay on sender side	300 ns
protocolRTE	is the percentage of protocol time (see Formula (16) in 8.2.4.2.10)	50 %
Queue_delay	is the Queue delay in a switch	0 s
RedundancyManagement	is the time needed for management functions to support redundancy	0 s
STTr	is the receiver stack traversal time	0 s
STTs	is the sender stack traversal time	0 s
Time_synchron_accuracy	is the time synchronization accuracy	1 µs
tt	is the transfer time (80 ns/octet for 100 Mbit/s, 8 ns/octet for 1 Gbit/s)	80 ns
SCF	See IEC 61158–5–10, 8.3.10.4.2	32
RR	See IEC 61158–5–10, 8.3.10.4.2	1

8.4.4.3.2 MinDeviceInterval=31,25 µs

Table 81 specifies the consistent set of performance indicators using a network bandwidth of 100 Mbit/s, wired or fiber optic. The values are based of the figures given in Table 82 and the methods or algorithm given in 8.2.4.2. This consistent set of performance indicators shall be tested for devices (not wireless) that claim compliance with CP 3/6, form together a DFP group, claim conformance to the apoplication class “high performance” and support the given MinDeviceInterval.

Table 81 – CP 3/6: Consistent set of PIs for MinDeviceInterval=31,25 µs and NumberOfSwitches=10

Performance indicator	Value	Constraints
Delivery time	31,25 µs watch dog factor × 31,25 µs	Without failure Frames lost; (See 8.1, MinDeviceInterval = 31,25 µs)
Number of end-stations	10	Using 2 port switches and line topology; a switch is also an end-station
Number of switches between end-stations	8	–
Throughput RTE	3 264 000 octets/s	–
Non-RTE bandwidth	34,6 %	100 Mbit/s and related to 1 ms. Any IEEE 802.3 frames supported.
Time synchronization accuracy	< 1 ms	Synchronization of local time [c]
	< 1 µs	Synchronization of synchronous application
Redundancy recovery time	< 0 ms < 200 ms	RT_CLASS_3 [a]: single failure RTA [b] retries = 3; RTA timeout factor = 100 ms
	< 100 µs < 200 ms	RT_CLASS_3 [a]: double failure (line break and surge) watch dog factor = 3; delivery time = 31,25 µs RTA [b] retry = 3; RTA time out factor = 100 ms

[a] The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.

[b] The attributes RTA Retries and RTA Timeout Factor are specified in 8.3.10.4 of IEC 61158–5–10.

[c] Optional.

Table 82 – CP 3/6: Assumed values for consistent set of PI calculation

Symbol	Definition	Value
cd	is the cable delay (see parameter cable_delay in IEC 61158–6–10)	5 ns
clt	is the total cable length	100 m
cta_R	is the application cycle time of the Receiver	1 µs
cta_S	is the application cycle time of the Sender	1 µs
ctc	is the communication cycle time (see Formula (12) in 8.2.4.2.2) and shall be equal or longer than MinDeviceInterval	31,25 µs
data	is the complete Ethernet frame	118 octets
EthernetDataRate	is the Ethernet data rate of the network	Mbit/s
MAC_delay	is the delay on MAC layer	1 µs
NonRTE	is the percentage of non-RTE bandwidth	%
od	is any other delays, e. g. signal forwarding in a ring	0 s
pd	is the propagation delay (see Formula (13) in 8.2.4.2.2)	–
Phy_R_delay	is the Phy delay on receiver side; the maximum value of the application profile “high performance”	210 ns
Phy_S_delay	is the Phy delay on sender side; the maximum value of the application profile “high performance”	90 ns
protocolRTE	is the percentage of protocol time (see Formula (16) in 8.2.4.2.10)	50 %
Queue_delay	is the Queue delay in a switch	0 s
RedundancyManagement	is the time needed for management functions to support redundancy	0 s
STTr	is the receiver stack traversal time	0 s
STTs	is the sender stack traversal time	0 s
Time_synchron_accuracy	is the time synchronization accuracy	1 µs
tt	is the transfer time (80 ns/octet for 100 Mbit/s, 8 ns/octet for 1 Gbit/s)	80 ns
SCF	See IEC 61158–5–10, 8.3.10.4.2	1
RR	See IEC 61158–5–10, 8.3.10.4.2	1

9 Communication Profile Family 4 (P-NET) – RTE communication profiles

9.1 General overview

Communication Profile Family 4 defines profiles based on IEC 61158-2 Type 4, IEC 61158-3-4, IEC 61158-4-4, IEC 61158-5-4 and IEC 61158-6-4, which corresponds to parts of a communication system commonly known as P-NET®[6].

– Profile 4/1 P-NET RS 485

This profile contains AL, DLL and PhL services and protocol references with an IEC 61158 compliant application access. Profile 4/1 is based on ANSI TIA/EIA-485-A, and allows up to 125 devices of normal or simple class to communicate on the same physical link, in half duplex mode.

– Profile 4/2 *Void*

[6] P-NET is a trade name of International P-NET User Organisation ApS (IPUO). This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name P-NET. Use of the trade name P-NET requires permission from the trade name holder.

– Profile 4/3 P-NET on IP

  This profile contains AL and DLL services and protocol references with an IEC 61158 compliant application access. Profile 4/3 is based to ISO/IEC 8802-3, and allows up to 125 devices of normal class to communicate on the same logical link, in full-duplex mode.

Profile 4/1 is described in IEC 61784-1, whereas profile 4/3 is described in this part of IEC 61784.

9.2 Profile 4/3, P-NET on IP

9.2.1 Physical layer

The physical layer of the P-NET on IP profile is implemented according to ISO/IEC 8802-3 or ISO/IEC 8802-11. P-NET devices for this profile shall use a data rate of at least 10 Mbit/s and full-duplex mode.

9.2.2 Data-link layer

9.2.2.1 DLL service selection

Table 83 holds the data-link layer service selections from IEC 61158-3-4 for this profile.

Table 83 – CP 4/3: DLL service selection

Clause	Header	Presence	Constraints
1	Scope and object	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Data Link Service and concepts	YES	–
5	DL-management Service	–	–
5.1	Scope and inheritance	NO	–
5.2	Facilities of the DL-management service	Partial	Bullets a) and b)
5.3	Model of the DL_management service	YES	–
5.4	Constraints on sequence of primitives	Partial	Only the parts referring to DLM-Set and DLM-Get
5.5	DL-Set	YES	–
5.6	DL-Get	YES	–
5.7 – 5.8	–	NO	–

9.2.2.2 DLL protocol selection

Table 84 holds the data-link layer protocol selections from IEC 61158-4-4 for this profile.

Table 84 – CP 4/3: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope and object	YES	–
2	Normative references	Partial	Used if needed
3	Terms and definitions	Partial	Used when applicable
4	Symbols and abbreviations	Partial	Used when applicable
5	Data Link Protocol definition	YES	See [a]
[a] A device shall provide at least the necessary protocol options to fulfil the supported services.			

9.2.3 Application layer

9.2.3.1 AL service selection

Table 85 holds the Application layer service selections from IEC 61158-5-4 for this profile.

Table 85 – CP 4/3: AL service selection

Clause	Header	Presence	Constraints
Whole document	Application layer service definition – Type 4 elements	YES	–

Normal class devices shall support the Real Variable Objects needed for the variable types, which are actually present in the device, and Proxy Variable Objects for all of the variable types listed in IEC 61158-5-4, 5.2.

9.2.3.2 AL protocol selection

Table 86 holds the Application layer protocol selections from IEC 61158-6-4 for this profile.

Table 86 – CP 4/3: AL protocol selection

Clause	Header	Presence	Constraints
Whole document	Application layer protocol specification – Type 4 elements	YES	See [a]
[a] A device shall provide at least the necessary protocol options to fulfil the supported services.			

9.2.4 Performance indicator selection

9.2.4.1 Performance indicator overview

Table 87 – CP 4/3: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	Application dependant
Number of end-stations	YES	Up to 125
Basic network topology	YES	
Number of switches between end-stations	YES	Communication between switches must be at least 100 Mbit/s
Throughput RTE	YES	
Non-RTE bandwidth	YES	
Time synchronization accuracy	NO	
Non-time-based synchronization accuracy	YES	
Redundancy recovery time	YES	

9.2.4.2 Performance indicator dependencies

Table 88 shows the overview of performance indicators applicable to CP 4/3.

Table 88 – CP 4/3: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Non-time- based synchron. accurancy	Redundancy recovery time
Delivery time		YES 9.2.4.2.1	YES 9.2.4.2.3	YES 9.2.4.2.1	YES 9.2.4.2.1	NO	NO	YES 9.2.4.2.2
Number of end-stations	YES 9.2.4.2.1		NO	NO	YES 9.2.4.2.1	YES 9.2.4.2.1	NO	NO
Basic network topology	YES 9.2.4.2.3	NO		NO	NO	NO	NO	NO
Number of switches between end-stations	YES 9.2.4.2.1	NO	NO		YES 9.2.4.2.1	YES 9.2.4.2.1	YES 9.2.4.2.1	YES 9.2.4.2.2
Throughput RTE	YES 9.2.4.2.1	YES 9.2.4.2.1	NO	YES 9.2.4.2.1		NO	NO	YES 9.2.4.2.2
Non-RTE bandwidth	NO	YES 9.2.4.2.1	NO	YES 9.2.4.2.1	NO		NO	NO
Non-time-based synchronization accuracy	YES 9.2.4.2.4	NO	NO	YES 9.2.4.2.4	NO	NO		NO
Redundancy recovery time	NO	NO	NO	YES 9.2.4.2.2	NO	NO	NO	

9.2.4.2.1 Calculation of Delivery time

Delivery time is calculated according to Formula (17). Derivation of this formula is given in A.3.6. Switches are numbered as #1 at senders connection up to #NoS at the receivers connection.

$$DT = STTs + STTr + NoNt\ (ttES + pd + QTES) + cd \sum_{i=1}^{NoS-1} (NoNs(i)(NoS - i)(ttSS + pd + QTSS)) \quad (17)$$

where

cd	is the cable delay time;
DT	is the delivery time;
NoNs[x]	is the number of RTE end-stations connected to switch No x. This includes number of RTE end-stations connected to the switch by other switches, which are not included in the path from sender to receiver. Switches are numbered as #1 at senders connection up to #NoS at the receivers connection;
NoNt	is the number of RTE end-stations, in total;
NoS	is the number of switches in path from sender to receiver;
pd	is the propagation delay within a Switch;
QTES	is the Ethernet enforced quiet time on end-station to switch link;
QTSS	is the Ethernet enforced quiet time on switch-to-switch link;
STTr	is the receiver stack transversal time including Phy and MAC;
STTs	is the sender stack transversal time including Phy and MAC access interval restriction;
ttES	is the P-NET transfer time RTE end-station to switch at maximum APDU size;
ttSS	is the P-NET transfer time switch-to-switch at maximum APDU size.

The delivery time is increased with a timeout value in the event of a lost frame. The timeout value is application dependent, and can be configured for each network in an application. The typical timeout value is 100 ms.

9.2.4.2.2 Redundancy recovery time

The redundancy recovery time depends on the switches that are used for the specific application. It is recommended to use switches that support the rapid spanning tree protocol (RSTP), or similar, to minimize the redundancy recovery time.

9.2.4.2.3 Basic network topology

When using WLAN, the total delay caused by wireless transmissions may change depending on the signal/noise ratio. To obtain a required delivery time in a system using WLAN, the worst case delay time for the WLAN equipment shall be included in the cable delay time, cd.

9.2.4.2.4 Non time-base synchronization accuracy

The non time-base synchronization accuracy is calculated according to Formula (18).

$$\textit{Non time-base synchronization accuracy} = DT - DTb \quad (18)$$

where

DTb	is the delivery time, calculated by best-case values;
DT	is the delivery time, calculated by worst-case values.

9.2.4.2.5 Throughput RTE

The throughput RTE is calculated according to Formulae (19) and (20).

$$Minimum\ RTE\ Throughput = FS \times minAPDUs \tag{19}$$

$$Maximum\ RTE\ Throughput = FS \times maxAPDUs \tag{20}$$

where

FS	is the number of frames allowed to be sent per second for one RTE end-station;
minAPDUs	is the size of the minimum APDU;
maxAPDUs	is the size of the maximum APDU.

9.2.4.2.6 Non-RTE bandwidth

The time not occupied by RTE communication can be used for non-RTE communication. Each RTE end-station has a network access restriction that limits the number of frames produced onto the RTE network.

The RTE load is determined by the critical switch-to-switch link between two devices engaged in a non-RTE communication. The critical switch-to-switch link is where the most RTE frames can occur.

The non-RTE bandwidth (%) can be calculated by using Formula (21).

$$Non\text{-}RTE\ Throughput = (1 - (NoCEN \times NoAS)(ttSS+QTSS)) \times 100 \tag{21}$$

where

NoCEN	is the number of RTE end-stations which can produce frames on the critical switch-to-switch link;
NoAS	is the number of accesses allowed per device per second;
ttSS	is the P-NET transfer time switch-to-switch at maximum APDU size;
QTSS	is the Ethernet enforced quiet time on switch-to-switch link.

See example of non-RTE bandwidth calculation in A.3.3.

9.2.4.3 Consistent set of performance indicators

Table 89 shows a consistent set of performance indicators for a typical configuration for factory automation.

Details for calculating the performance indicators are given in Clause A.2.

Parameters used for the calculation of Table 89 are shown in Table 90. All these parameters are the result of the described scenario and the related calculations of performance indicators.

Table 89 – CP 4/3: Consistent set of PIs

Performance indicator	Value	Constraints
Delivery time	6,3 ms	
Minimum delivery time	0,564 ms	
Throughput RTE minimum	5 Koctets/s	
Throughput RTE maximum	64 Koctets/s	
Non-RTE bandwidth	75 %	Non-RTE device to non-RTE device
Non-time-based synchronization accuracy	5,7 ms	
Redundancy recovery time	1 s	Example value. See 9.2.4.2.2
Number of RTE end-stations, in total	30	
Number of switches in path from sender to receiver	4	

Table 90 – Parameters for calculation of consistent set of PIs

Symbol	Description	Value
STTs	Sender stack transversal time including Phy and MAC access interval restriction	1 250 µs
STTR	Receiver stack transversal time including Phy and MAC	250 µs
ttESmin	P-NET transfer time at 10 Mbit/s (at min APDU size)	57 µs
ttES	P-NET transfer time at 10 Mbit/s (at maximum APDU size)	114,4 µs
ttSS	P-NET transfer time at 100 Mbit/s (at maximum APDU size)	11,44 µs
QTES	Ethernet enforced quiet time at 10 Mbit/s	9,4 µs
QTSS	Ethernet enforced quiet time at 100 Mbit/s	0,94 µs
cd	Cable delay. Sum of cable from sender to receiver is 200 m	1 µs
pd	Propagation delay within a switch. Required minimum value	7 µs
NoS	Number of switches in path from sender to receiver	4
NoNt	Number of RTE end-stations, in total	30
NoNs[1]	Number of RTE end-stations connected to switch number 1	10
NoNs[2]	Number of RTE end-stations connected to switch number 2	5
NoNs[3]	Number of RTE end-stations connected to switch number 3	5
NoNs[4]	Number of RTE end-stations connected to switch number 4	10

10 Communication Profile Family 6 (INTERBUS®[7]) – RTE communication profiles

10.1 General overview

Communication Profile Family 6 (CPF 6) defines communication profiles based on IEC 61158 series Type 8 and Type 10 specifications, which correspond to parts of the communication systems commonly known as INTERBUS and PROFINET.

7 INTERBUS is the trade name of Phoenix Contact GmbH & Co. KG., control of trade name use is given to the non-profit organisation INTERBUS Club. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name INTERBUS. Use of the trade name INTERBUS requires permission from the INTERBUS Club.

In this part of IEC 61784, the following communication profiles are specified for CPF 6:

– Profile 6/4

  This profile defines service and protocol selections together with a mapping for a linking-device connecting Type 8 and Type 10 communication systems. It comprises CP 6/1 master and CP 3/4 device together with a mapping.

– Profile 6/5

  This profile defines service and protocol selections together with a mapping for a linking-device connecting Type 8 and Type 10 communication systems. It comprises CP 6/1 master and CP 3/5 device together with a mapping.

– Profile 6/6

  This profile defines service and protocol selections together with a mapping for a linking-device connecting Type 8 and Type 10 communication systems. It comprises CP 6/1 master and CP 3/6 device together with a mapping.

Figure 6 shows the linking-device CPs and the relation to other Type 8 and Type 10 CPs.

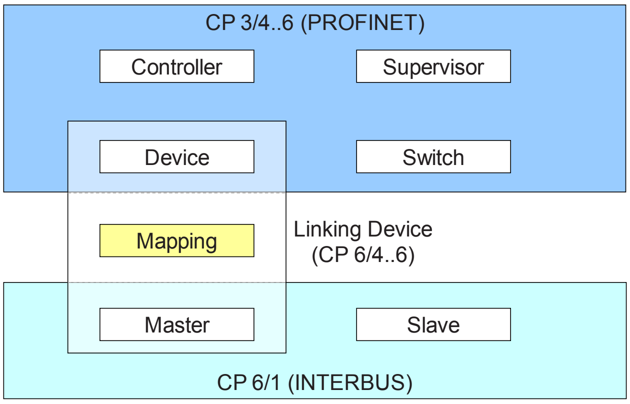

Figure 6 – Linking-device communication profiles RTE-network context

Linking-devices, which comply with a communication profile can be further classified by a CP identifier. The CP identifier assignment is shown in Table 91.

Table 91 – CPF 6: device CP identifier assignment

Profile	Linking device
Profle 6/4	649
Profle 6/5	659
Profle 6/6	669

Each communication profile provides a well-defined set of provisions. For a distinct device further selections of services, parameters and parameter values shall be made. These selections should be described according to ISO 15745-3 as INTERBUS device profiles in the form of an INTERBUS device profile exchange description. An INTERBUS device profile based on a CP shall specify the CP identifier in the following format:

<communicationEntity … communicationProfile="[CP identifier]" …>

10.2 Profile 6/4

10.2.1 Mapping

Type 8 devices shall be assigned to Type 10 slots or Type 10 subslots.

NOTE 1 The mapping concept itself is not part of the communication profile. The mapping concept used could be described in the device description of the linking-device according to ISO 15745-1.

Type 10 slots or subslots could have 1 or more Type 8 devices assigned to it.

Figure 7 depicts the mapping principle. The data mapping is shown in Figure 8.

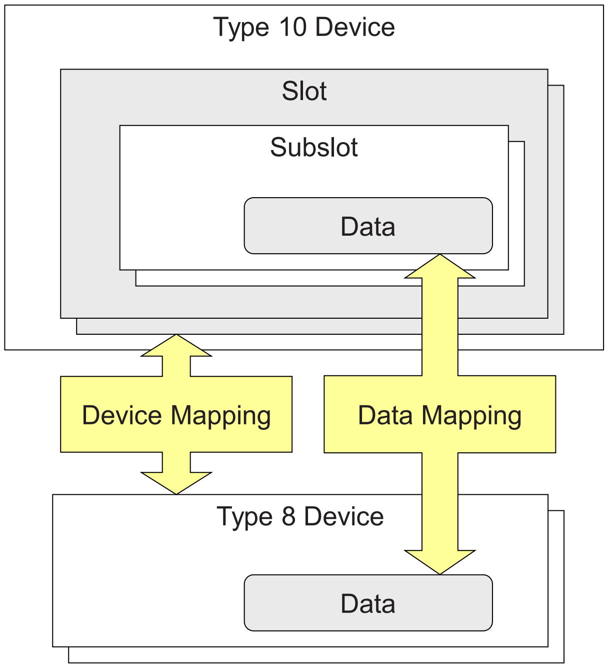

Figure 7 – Linking-device mapping principle

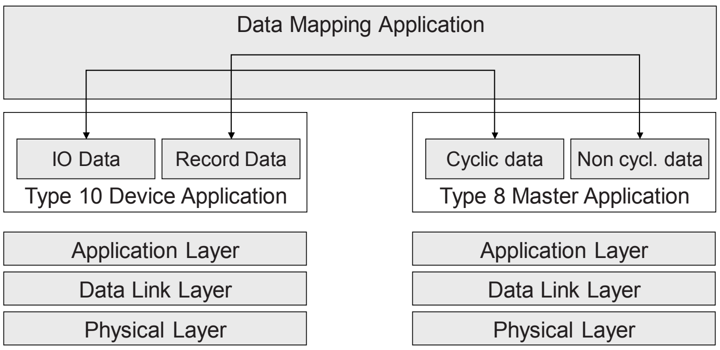

Figure 8 – Data Mapping

The specific applications realize the services of types 8 and 10 according to the defined communication profiles. The data objects of the network applications are interconnected with a mapping application which shall implement the following behavior:

- the Input/Output data of the subslot shall be mapped to the cyclic data of the corresponding Type 8 slaves;

- the process data status information (IOPS/IOCS) of the subslot shall be locally generated because there is no corresponding process data status in Type 8 Systems;
- the record data objects of the subslot shall be mapped to the non cyclic data of the corresponding Type 8 slaves.

NOTE 2 It is possible to describe the Input/Output data and the record data of a subslot in the device description of the linking-device according to ISO 15745-1.

10.2.2 Type 10 service and protocol selection

10.2.2.1 Physical layer

The Type 10 physical layer of this profile shall be according to IEEE 802.3. Linking-devices shall use a data rate of at least 100 Mbit/s and full-duplex mode at least for one port. The auto negotiation and crossover function specified in IEEE 802-3 shall be used.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-3.

10.2.2.2 Data-link layer

The Type 10 data-link layer of a linking-device shall be according to IEEE 802.3, IEEE 802.1AB, IEEE 802.1D, and IEEE 802.1Q.

From the various optional Management Information Bases (MIB) at least the LLDP MIB (see IEEE 802.1AB) and SNMP MIB-II (see RFC 1213) are required.

10.2.2.3 Application layer

10.2.2.4 AL service selection

The linking-device shall provide the CP 3/4 service selection as specified in 8.2.3.2.1.

10.2.2.5 AL protocol selection

The linking-device shall provide the CP 3/4 protocol selection as specified in 8.2.3.2.1.

10.2.3 Type 8 service and protocol selection

10.2.3.1 Physical layer

The linking-device shall provide the CP 6/1 master PhL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-6.

10.2.3.2 Data-link layer

The linking-device shall provide the CP 6/1 master DLL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

10.2.3.3 Application layer

The linking-device shall provide the CP 6/1 master AL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

10.2.4 Performance indicator selection

10.2.4.1 Performance indicator overview

Table 92 specifies the relevant performance indicators for the Type 10 network node of a linking-device.

Table 92 – Linking-device Type 10 network PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	See 10.2.4.2.2 for the delivery time of data from the Type 8 network
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	YES	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	–
Non-time-based synchronization accuracy	–	–
Redundancy recovery time	YES	For the Type 10 network only

10.2.4.2 Performance indicator dependencies

10.2.4.2.1 Performance indicator dependency matrix

Table 61 specifies the dependencies of the performance indicators of the Type 10 network of a linking-device.

10.2.4.2.2 Delivery time for Type 8 slave data

The performance indicator delivery time for the Type 10 network (DT10) is defined in 8.2.4.2.2.

The delivery time for data from a Type 8 slave can be calculated by Formula (22).

$$DTLD = DT10 + cta\_M + [M \times 13 \times (8 + sl8) + 3 \times a] \times T_{bit} + t_S \quad (22)$$

where

DTLD	is the total delivery time between a Type 8 slave and a Type 10 entity;
DT10	is the delivery time of the Type 10 network;
Cta_M	is the application cycle time of the mapping application in the linking-device;
M	is the Type 8 Master implementation factor;
n	is the number of data octets (user data; payload);
sl8	is the number of Type 8 slaves connected to the linking-device;
T_{bit}	is the nominal bit duration (see 27.2 in IEC 61158-2);
t_S	is the software processing time of the Type 8 master (application specific).

10.2.4.3 Consistent set of performance indicators

The consistent set of performance indicators for the Type 10 network is described in 8.2.4.3.

10.3 Profile 6/5

10.3.1 Mapping

The mapping is specified in 10.2.1.

10.3.2 Type 10 service and protocol selection

10.3.2.1 Physical layer

The Type 10 physical layer of this profile shall be according to IEEE 802.3. Linking-devices shall use a data rate of at least 100 Mbit/s and full-duplex mode at least for one port. The auto negotiation and crossover function specified in IEEE 802.3 shall be used.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-3.

10.3.2.2 Data-link layer

The Type 10 data-link layer of a linking-device shall be according to ISO/IEC 8802-3, IEEE 802.1AB, IEEE 802-1D, and IEEE 802-1Q.

From the various optional Management Information Bases (MIB) at least the LLDP MIB (see IEEE 802.1AB) and SNMP MIB-II (see RFC 1213) are required.

10.3.2.3 Application layer

10.3.2.4 AL service selection

The linking-device shall provide the CP 3/5 service selection as specified in 8.3.3.1.1

10.3.2.5 AL protocol selection

The linking-device shall provide the CP 3/5 protocol selection as specified in 8.3.3.2.1.

10.3.3 Type 8 service and protocol selection

10.3.3.1 Physical layer

The linking-device shall provide the CP 6/1 master PhL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-6.

10.3.3.2 Data-link layer

The linking-device shall provide the CP 6/1 master DLL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

10.3.3.3 Application layer

The linking-device shall provide the CP 6/1 master AL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

10.3.4 Performance indicator selection

10.3.4.1 Performance indicator overview

See 10.2.4.1.

10.3.4.2 Performance indicator dependencies

See 10.2.4.2.

10.3.4.3 Consistent set of performance indicators

The consistent set of performance indicators for the Type 10 network is described in 8.3.4.3.

10.4 Profile 6/6

10.4.1 Mapping

The mapping is specified in 10.2.1.

10.4.2 Type 10 service and protocol selection

10.4.2.1 Physical Layer

The Type 10 physical layer of this profile shall be according to IEEE 802.3. Linking-devices shall use a data rate of at least 100 Mbit/s and full-duplex mode at least for one port. The auto negotiation and crossover function specified in IEEE 802.3 shall be used.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-3.

10.4.2.2 Data-link layer

The Type 10 DLL of a linking-device shall be according to IEEE 802.3, IEEE 802.1AB, IEEE 802.1D, and IEEE 802.1Q.

From the various optional Management Information Bases (MIB) at least the LLDP MIB (see IEEE 802.1AB) and SNMP MIB-II (see RFC 1213) are required.

10.4.2.3 Application layer

10.4.2.4 AL service selection

The linking-device shall provide the CP 3/6 service selection as specified in 8.4.3.1.1.

10.4.2.5 AL protocol selection

The linking-device shall provide the CP 3/6 service selection as specified in 8.4.3.2.1.

10.4.3 Type 8 service and protocol selection

The Type 8 service and protocol selection is specified in 10.3.3.

10.4.4 Performance indicator selection

10.4.4.1 Performance indicator overview

See 10.2.4.1.

10.4.4.2 Performance indicator dependencies

See 10.2.4.2.

10.4.4.3 Consistent set of performance indicators

The consistent sets of performance indicators for the Type 10 network is described in 8.4.4.3.

11 Communication Profile Family 10 (Vnet/IP[8]) – RTE communication profiles

11.1 General overview

Communication Profile Family 10 (CPF 10) defines communication profiles using the principles, methodology and model of ISO/IEC 7498-1. In addition, it also follows the three-layer basic fieldbus reference model described in IEC 61158-1.

The OSI model provides a layered approach to communication standards, whereby the layers can be developed and modified independently. CPF 10 is based on the three-layer structure, and each layer of OSI seven layers is mapped onto these three layers as follows.

Functions of the intermediate OSI layers, layers 5, 6 and 7, are consolidated into the Application layer.

Functions of the intermediate OSI layers, layers 2, 3 and 4, are consolidated into the data-link layer.

Likewise, some features common to users of the Fieldbus Application layer are provided to simplify user operation.

Table 93 shows the OSI layers, their functions and the equivalent layers in the CPF10 layer model.

Table 93 – OSI layers and CPF 10 layers

OSI layer	Function	CPF 10 layer
7 Application	Translates demands placed on the communication stack into a form understood by the lower layers and vice versa	Application
6 Presentation	Converts data to/from standardized network formats	
5 Session	Synchronizes and manages data	
4 Transport	Provides transparent reliable data transfer	Data-link
3 Network	Performs message routing	
2 Data-link	Controls access to the communication medium. Performs error detection	
1 Physical	Encodes/decodes signals for transmission/reception in a form appropriate to the communication medium. Specifies communication media characteristics	Physical

Table 94 shows an overview of the communication profile for CPF 10.

Table 94 – Overview of CPF 10 profile

Layer	Protocol
Application	IEC 61158-6-17
Transport	RFC 768 and IEC 61158-4-17
Network	RFC 791
Data-link	ISO/IEC 8802-2 and 8802-3
Physical	Either ISO/IEC 8802-3 or IEEE 802.3

8 Vnet/IP is a trade name of Yokogawa Electric Corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

11.2 Profile 10/1

11.2.1 Physical layer

ISO/IEC 8802-3 or IEEE 802.3 shall be used.

11.2.2 Data link layer

11.2.2.1 MAC sublayer

ISO/IEC 8802-3 shall be used.

11.2.2.2 LLC sublayer

ISO/IEC 8802-3 shall be used.

11.2.2.3 Network sublayer

11.2.2.3.1 General

Internet standard RFC 791 and its amendments and successors shall be used.

Internet standard RFC 2236 shall be used to perform multicasting.

11.2.2.3.2 Unicast address

IPv4 class C private address scope shall be used. Each subnetwork of a domain has the respective IP network address as follows.

IP address for the interface connected to the primary network:

192.168.(Domain number).(Host address)

IP address for the interface connected to the secondary network:

192.168.128+(Domain number).(Host address)

Each node of a redundant station has a respective IP host address as follows.

Host address: (Station number) X 2 or (Station number) X 2 + 1

11.2.2.3.3 Group address

IPv4 class D Organization-Local Scope shall be used as group addresses for multicasting. Both the primary network and the secondary network require two group addresses: one for multicasting to all stations in the domain, and another for multicasting to all stations in the multi-domain network.

To assign these group addresses to the stations, AD-HOC Block group address 224.0.23.33 may be used.

NOTE This group address is registered with the Internet Assigned Numbers Authority (IANA).

11.2.2.3.4 TOS

The following four TOS parameter values shall be used for the data-link service:

– time synchronization;
– high priority;
– low priority;

– general purpose.

11.2.2.4 Transport sublayer

11.2.2.4.1 Transport service selection

Internet standard RFC 768 (UDP) and its amendments and successors, and the data-link layer specified in IEC 61158-3-17 and IEC 61158-4-17 shall be used.

UDP port number 5313 shall be used.

NOTE This UDP port number is registered with the Internet Assigned Numbers Authority (IANA).

Table 95 specifies the DLL service selection within IEC 61158-3-17.

Table 95 – CP 10/1: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative reference	YES	–
3	Definitions	YES	–
4	Overview of the data-link layer service	YES	–
5	DLSAP management service	YES	–
6	Connectionless-mode Data Link Service	YES	–
7	DL-management Service	YES	–

11.2.2.4.2 Transport protocol selection

Table 96 specifies the DLL protocol selection within IEC 61158-4-17.

Table 96 – CP 10/1: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative reference	YES	–
3	Definitions	YES	–
4	Overview of the DL-protocol	YES	–
5	DLPDU-parameter structure and encoding	YES	–
6	Local parameters and resources	YES	–
7	DL-service elements of procedure	YES	–
8	DL-support protocol	YES	–

11.2.2.4.3 Parameter selection

Table 97 shows the parameter selection.

Table 97 – Transport Layer Parameter selection

Parameter Symbol	Parameter name	Usage	Value
P(ND)	max-domains	M	31
P(HC)	max-hop-count	M	7
P(NS)	max-stations	M	64
$P(GA_{1A})$	IP-group-address-1A	M	239.192.24.0
$P(GA_{1B})$	IP-group-address-1B	M	239.192.24.1
$P(GA_{2A})$	IP-group-address-2A	M	239.192.24.4
$P(GA_{2B})$	IP-group-address-2B	M	239.192.24.5
$P(AB_{DA})$	IP-base-address-domain-A	M	192.168.0.0
$P(AB_{DB})$	IP-base-address-domain-B	M	192.268.128.0
$P(MRC_{AUS})$	max-retry-count-AUS	M	5
$P(MRC_{ASS})$	max-retry-count-ASS	M	5
P(MOS)	max-outstanding-number	M	10
$P(TNR_{AUS})$	max-response-time-AUS	M	50 ms
$P(TNR_{ASS})$	max-response-time-ASS	M	500 ms
$P(TWT_{AUS})$	wait-time-AUS	M	100 ms
$P(TWT_{ASS})$	wait-time-ASS	M	100 ms
$P(TID_{ASS})$	inter-DTPDU-time	M	500 ms
P(MC)	macro-cycle-period	M	100 ms
$P(SD_{UUS})$	starting-delay-UUS	M	{1,11,21,31,41,56,66,76,86} ms
$P(SD_{AUS})$	starting-delay-AUS	M	{1,11,21,31,41,56,66,76,86} ms
$P(SD_{ASS})$	starting-delay-ASS	M	{6,16,26,36,51,61,71,81,91} ms
$P(SD_{MUS})$	starting-delay-MUS	M	{8,28,48,68,88} ms
$P(SD_{MSS})$	starting-delay-MSS	M	{46} ms
$P(TD_{UUS})$	time-duration-UUS	M	1 ms
$P(TD_{AUS})$	time-duration-AUS	M	1 ms
$P(TD_{ASS})$	time-duration-ASS	M	1 ms
$P(TD_{MUS})$	time-duration-MUS	M	1 ms
$P(TD_{MSS})$	time-duration-MSS	M	1 ms
$P(TO_{UUS})$	offset-time-UUS	M	1 ms
$P(TO_{AUS})$	offset-time-AUS	M	1 ms
$P(TO_{ASS})$	offset-time-ASS	M	1 ms
$P(TO_{MUS})$	offset-time-MUS	M	1 ms
$P(TO_{MSS})$	offset-time-MSS	M	1 ms
$P(DV_{UUS})$	divisor-for-grouping-UUS	M	5
$P(DV_{AUS})$	divisor-for-grouping-AUS	M	5
$P(DV_{ASS})$	divisor-for-grouping-ASS	M	5
$P(DV_{MUS})$	divisor-for-grouping-MUS	M	5
$P(DV_{MSS})$	divisor-for-grouping-MSS	M	5
P(KS)	key size	M	4 octet
P(AS)	authentication field size	M	2 octet
P(PN)	prime-number	M	0b01011001
P(BS)	base-number	M	251
P(UD)	key-update-time	M	3 600 s

11.2.3 Application layer

11.2.3.1 General

The application layer specified in IEC 61158-5-17 and IEC 61158-6-17 shall be used.

11.2.3.2 AL service selection

Table 98 specifies the AL service selection within IEC 61158-5-17.

Table 98 – CP 10/1: AL service selection

Clause	Header	Presence	Constraints
1	Scope and objective	YES	–
2	Normative reference	YES	–
3	Definitions	YES	–
4	Concepts	YES	–
5	ASEs	YES	–
6	ARs	YES	–
7	Summary of FAL classes	YES	–
8	Permitted FAL services by AREP role	YES	–

11.2.3.3 AL protocol selection

Table 99 specifies the AL protocol selection within IEC 61158-6-17.

Table 99 – CP 10/1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative reference	YES	–
3	Definitions	YES	–
4	Abstract syntax description	YES	–
5	Transfer syntax	YES	–
6	FAL protocol state machines structure	YES	–
7	AP-Context state machine	YES	–
8	FAL Service Protocol Machines (FSPMs)	YES	–
9	Application Relationship Protocol Machines (ARPMs)	YES	–
10	DLL Mapping Protocol Machine (DMPM)	YES	–

11.2.4 Performance indicator selection

11.2.4.1 Performance indicator overview

Table 100 shows the overview of performance indicators applicable to CP 10/1.

Table 100 – CP 10/1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	None
Number of end-stations	YES	None
Basic network topology	YES	None
Number of switches between end-stations	YES	None
Throughput RTE	YES	None
Non-RTE bandwidth	YES	None
Time synchronization accuracy	YES	None
Non-time-based synchronization accuracy	NO	–
Redundancy recovery time	YES	None

11.2.4.2 Performance indicator dependencies

11.2.4.2.1 General

Table 101 shows the dependencies between performance indicators for CP 10/1.

Table 101 – CP 10/1: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchronization accuracy	Redundancy recovery time
Delivery time		NO	YES 11.2.4.2.2	YES 11.2.4.2.2	NO	NO	NO	NO
Number of end-stations	NO		YES 11.2.4.2.3	YES 11.2.4.2.3	NO	NO	NO	NO
Basic network topology	YES 11.2.4.2.2	YES 11.2.4.2.3		YES 11.2.4.2.3	NO	NO	NO	NO
Number of switches between end-stations	NO	NO	YES 11.2.4.2.3		NO	NO	NO	NO
Throughput RTE	NO	NO	YES 11.2.4.2.4	NO		NO	NO	NO
Non-RTE bandwidth	NO	NO	YES 11.2.4.2.5	NO	NO		NO	NO
Time synchronization accuracy	NO	NO	YES 11.2.4.2.6	NO	NO	NO		NO
Redundancy recovery time	NO	NO	YES 11.2.4.2.7	NO	NO	NO	NO	

11.2.4.2.2 Calculation of delivery time

The actual delivery time can be calculated by Formula (23).

$$DT = STTs + STTr + Trate \times Dlen + Cdly \times Clen + Spd \times NoS \quad (23)$$

where

DT	is the delivery time;
STTs	is the sender stack traversal time including PhL, DLL and AP;
STTr	is the receiver stack traversal time including PhL, DLL and AP;
Trate	is the transfer bit rate;
Dlen	is the bit length of the complete Ethernet frame;
Cdly	is the cable delay;
Clen	is the cable length;
Spd	is the switch delay under not congested condition;
NoS	is the number of switches.

The maximum delivery time for communication between two end-stations belonging to the same domain can be calculated by Formula (24).

$$DTmax1 = 20\ ms + Cdly \times Clen + Spd \times NoS \quad (24)$$

where

DTmax1	is the maximum delivery time for communication between two end-stations belonging to the same domain;
Cdly	is the cable delay;
Clen	is the cable length;
Spd	is the switch delay under not congested condition;
NoS	is the number of switches.

The maximum delivery time for communication between two end-stations belonging to different domains can be calculated by Formula (25).

$$DTmax2 = 50\ ms + Cdly \times Clen + Spd \times NoS \quad (25)$$

where

DTmax2	is the maximum delivery time for communication between two end-stations belonging to different domains;
Cdly	is the cable delay;
Clen	is the cable length;
Spd	is the switch delay under not congested condition;
NoS	is the number of switches.

The maximum delivery time with one lost frame for communication between two end-stations belonging to the same domain can be calculated by Formula (26).

$$DTlost1 = 10\ ms + DTmax1 \quad (26)$$

where

DTlost1	is the maximum delivery time with one lost frame for communication between two end-stations belonging to the same domain;
DTmax1	is the maximum delivery time for communication between two end-stations belonging to the same domain.

The maximum delivery time with one lost frame for communication between two end-stations belonging to different domains can be calculated by Formula (27).

$$DTlost2 = 150\ ms + DTmax2 \tag{27}$$

where

DTlost2	is the maximum delivery time with one lost frame for communication between two end-stations belonging to different domains;
DTmax2	is the maximum delivery time for communication between two end-stations belonging to different domains.

11.2.4.2.3 Network structure restriction

If the network consists of only one domain, the number of the RTE end-stations is restricted to 64.

If the network consists of more than two domains, the number of RTE end-stations in the domain is restricted to 64. The maximum number of the domain shall be 64.

The topology of interconnection among domains shall be a tree topology.

The topology of interconnection among bridges in a domain shall be a tree topology or a ring topology.

The number of switches between any two end-stations in a same domain shall be less than 7, and the number of routers (layer-3-switches) between any two domains shall be less than 4.

11.2.4.2.4 Throughput RTE restriction

The throughput RTE which is generated by communication among end-stations which belong to the same domain shall be limited to less than 10 Moctets per second.

The throughput RTE which is generated by communication going out from any domain shall be limited to less than 10 Moctets per second. And the throughput RTE which is generated by communication coming into any domain shall be limited to less than 10 Moctets per second.

11.2.4.2.5 Non-RTE bandwidth restriction

The non-RTE bandwidth shall be less than 500 Mbit/s. If the network consists of more than two domains, routers shall control the non-RTE traffic in order to make the non-RTE bandwidth of any domain less than 500 Mbit/s, otherwise total non-RTE bandwidth generated in the network shall be less than 500 Mbit/s.

11.2.4.2.6 Time synchronization accuracy

The time synchronization accuracy between any two end nods which belong to the same domain is ±1 ms or less, and the time synchronization accuracy between any two end nods in the different domain is ±5 ms or less.

11.2.4.2.7 Redundancy recovery time

The redundancy recovery time for communication between any two end-stations which belong to the same domain is less than 200 ms, and the redundancy recovery time for communication between any two end-stations which belong to the different domains is less than 600 ms.

11.2.4.3 Consistent set of performance indicators

Table 102 shows a consistent set of performance indicators which is applicable to communication between two end-stations belonging to the same domain.

Table 102 – CP 10/1: Consistent set of PIs for the communication between two end-stations belonging to the same domain

Performance indicator	Value	Constraints
Delivery time	20 ms	Excluding cable_delay and nominal switch_delay
Number of end-stations	64	None
Number of switches between end-stations	7	None
Throughput RTE	10 M octet/s	None
Non-RTE bandwidth	0 % – 50 % (500 Mbit/s)	None
Time synchronization accuracy	< 1 ms	None
Non-time-based synchronization accuracy	Not applicable	–
Redundancy recovery time	<200 ms	None

Table 103 shows a consistent set of performance indicators which is applicable to communication between two end-stations belonging to different domains.

Table 103 – CP 10/1: Consistent set of PIs for the communication between two end-stations belonging to different domains

Performance indicator	Value	Constraints
Delivery time	50 ms	Excluding cable_delay and nominal switch_delay
Number of end-stations	4 096	–
Number of switches between end-stations	39	Including 4 layer-3-switches
Throughput RTE	10 M octet/s	–
Non-RTE bandwidth	0 % – 50 % (500 Mbit/s)	–
Time synchronization accuracy	< 5 ms	–
Non-time-based synchronization accuracy	Not applicable	–
Redundancy recovery time	< 600 ms	–

Table 104 shows a consistent set of performance indicators which is applicable to communication between two end-stations belonging to the same domain with one lost flame.

Table 104 – CP 10/1: Consistent set of PIs for the communication between two end-stations belonging to the same domain with one lost flame

Performance indicator	Value	Constraints
Delivery time	60 ms	Excluding cable_delay and nominal switch_delay
Number of end-stations	64	–
Number of switches between end-stations	7	–
Throughput RTE	10 M octet/s	–
Non-RTE bandwidth	0 % – 50 % (500 Mbit/s)	–
Time synchronization accuracy	< 1 ms	–
Non-time-based synchronization accuracy	Not applicable	–
Redundancy recovery time	< 200 ms	–

Table 105 shows a consistent set of performance indicators which is applicable to communication between two end-stations belonging to different domains with one lost flame.

Table 105 – CP 10/1: Consistent set of PIs for the communication between two end-stations belonging to different domains with one lost frame

Performance indicator	Value	Constraints
Delivery time	200 ms	Excluding cable_delay and nominal switch_delay
Number of end-stations	4 096	–
Number of switches between end-stations	39	Including 4 layer-3-switches
Throughput RTE	10 Moctet/s	–
Non-RTE bandwidth	0-50 % (500 Mbit/s)	–
Time synchronization accuracy	<5 ms	–
Non-time-based synchronization accuracy	Not applicable	–
Redundancy recovery time	<600 ms	–

12 Communication Profile Family 11 (TCnet[9]) – RTE communication profiles

12.1 General overview

Communication Profile Family 11 defines three types of communication profile based on IEC 61158-3-11, IEC 61158-4-11, IEC 61158-5-11 and IEC 61158-6-11 which corresponds to the communication systems commonly known as TCnet.

– Profile 11/1 (TCnet-star)

  This profile constitutes a TCnet communication system with star topology. It contains a selection of AL, and DLL services and protocol definitions from IEC 61158-3-11, IEC 61158-4-11, IEC 61158-5-11 and IEC 61158-6-11.

– Profile 11/2 (TCnet-loop 100 with physical layer of 100 Mbit/s)

[9] In Japan, TCnet is a trade name of TOSHIBA Corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

This profile constitutes a TCnet communication system with loop (ring) topology. It contains a selection of AL, and DLL services and protocol definitions from IEC 61158-3-11, IEC 61158-4-11, IEC 61158-5-11 and IEC 61158-6-11.

– Profile 11/3 (TCnet-loop 1G with physical layer of 1 000 Mbis/s)

  This profile constitutes a TCnet communication system with loop (ring) topology. It contains a selection of AL, and DLL services and protocol definitions from IEC 61158-3-11, IEC 61158-4-11, IEC 61158-5-11 and IEC 61158-6-11.

Table 106 shows the overview of TCnet profile set.

Table 106 – CPF 11: Overview of profile sets

Layer	Profile 11/1, profile 11/2, profile 11/3
Application	IEC 61158-5-11, IEC 61158-6-1
Data-link	IEC 61158-3-11, IEC 61158-4-11
Physical	ISO/IEC 8802-3

12.2 Profile 11/1

12.2.1 Physical layer

The physical layer of 100 Mbit/s shall be according to ISO/IEC 8802-3.

Connectors and cables are specified in IEC 61784-5-11 and IEC 61918.

12.2.2 Data-link layer

12.2.2.1 DLL services selection

Table 107 specifies the DLL service selection within IEC 61158-3-11.

Table 107 – CP 11/1: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	Relevant reference only
3	Terms, definitions, symbols, abbreviations and conventions	Partial	–
4	Data Link services and concept	YES	–
4.1	Overview	YES	–
4.2	General description of services	YES	–
4.3	TCC data service	YES	–
4.4	Detail description of sporadic message data service	YES	–
5	DL-management services	YES	–
5.1	General	YES	–
5.2	Facilities of the DL-Management service	YES	–
5.3	Service of the DL-management	YES	–
5.4	Overview of interactions	YES	–
5.5	Detail specification of service and interactions	YES	–

12.2.2.2 DLL protocol selection

Table 108 specifies the DLL protocol selection within IEC 61158-4-11.

Table 108 – CP 11/1: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	Relevant reference only
3	Terms, definitions, symbols and abbreviations	Partial	–
4	Overview of the DL-protocol	–	–
4.1	General	YES	–
4.2	Overview of the medium access control	YES	–
4.3	Service assumed from the PhL	YES	–
4.4	DLL architecture	–	–
4.4.1	Overview	YES	–
4.4.2	Star-architecture	YES	–
4.4.3	Loop-architecture	NO	–
4.5	Access control machine and schedule support functions	YES	–
4.6	Local parameters, variables, counters, timers and queues	–	–
4.6.1	Overview	YES	–
4.6.1.1	General		
4.6.1.2	Summary of variables, parameters, counters, timers for star-architecture	YES	–
4.6.1.3	Summary of variables, parameters, counters, timers for loop-architecture	NO	–
4.6.2	Type 11 common variables, parameters, counters, timers and queues	YES	Relevant values and features to star-architecture
4.6.3	Star-architecture specific variables, parameters counters timers and queues	YES	–
4.6.4	Loop-architecture specific variables, parameters, counters timers and queues	NO	–
5	General structure and encoding of PhIDEs and DLPDU and related element of procedure	YES	See Table 109
6	DLPDU-specific structure, encoding and elements of procedure	YES	See Table 110
7	DLE element of procedure	–	–
7.1	DLE elements of procedure for star-architecture	YES	–
7.2	DLE elements of procedure for loop-architecture	NO	–
7.3	Serializer and deserializer	YES	–
7.4	DLL management protocol	–	–
7.4.1	DLL management protocol for star-architecture	YES	–
7.4.2	DLL management protocol for loop-architecture	NO	–

Table 109 – CP 11/1: DLL protocol selection of Clause 5

Clause	Header	Presence	Constraints
5.1	Overview	YES	–
5.2	PhIDU structure and encoding	YES	–
5.3	Common MAC frame structure, encoding and elements of procedure	YES	–
5.4	Elements of the MAC frame	–	–
5.4.1	General	YES	–
5.4.2	Preamble field	YES	–
5.4.3	Start frame delimiter (SFD)	YES	–
5.4.4	Address field	YES	–
5.4.5	Length/type field	YES	–
5.4.6	Frame control field (FC)	–	–
5.4.6.1	Structure of FC field	YES	–
5.4.6.2	Frame type (F-type) field	YES	–
5.4.6.3	Priority field (Pri)	YES	Relevant features to star-architecture
5.4.7	Source node number field (SN)	YES	–
5.4.8	Data and pad field	YES	–
5.4.9	Frame check sequence (FCS)	YES	–
5.5	Order of bit transmission	YES	–
5.6	Invalid DLPDU	YES	–

Table 110 – CP 11/1: DLL protocol selection of Clause 6

Clause	Header	Presence	Constraints
6.1	General	YES	–
6.2	Synchronization DLPDU (SYN)	–	–
6.2.1	General	YES	–
6.2.2	Structure of SYN DLPDU	YES	–
6.2.3	Parameters of SYN DLPDU	–	–
6.2.3.1	Transmission permits node number (PN)	YES	Relevant features to star-architecture
6.2.3.2	Control word (CW)	–	–
6.2.3.2.1	CW for star-architecture	YES	–
6.2.3.2.2	CW for loop-architecture	NO	–
6.2.3.3	Slot time (ST)	YES	Relevant features to star-architecture
6.2.3.4	High-speed transmission period (Th)	YES	–
6.2.3.5	Medium-speed transmission period (Tm)	YES	–
6.2.3.6	Sporadic message transmission target-token-rotation-time period (Ts)	YES	Relevant features to star-architecture
6.2.3.7	Low-speed transmission period (Tl)	YES	–
6.2.3.8	Live list (LL)	YES	–
6.2.4	User data	YES	–
6.2.5	Sending SYN DLPDU	YES	–
6.2.6	Receiving SYN DLPDU	YES	–

Clause	Header	Presence	Constraints
6.3	Transmission complete DLPDU (CMP)	YES	–
6.4	In-ring request DLPDU (REQ)	–	–
6.4.1	General	YES	–
6.4.2	Structure of REQ DLPDU	YES	–
6.4.3	Node-mode – ESYN parameter	NO	–
6.4.4	Recipient node number (RN) Parameter	NO	–
6.4.5	User data of REQ DLPDU	YES	–
6.4.6	Sending REQ DLPDU	YES	–
6.4.7	Receiving REQ DLPDU	YES	–
6.5	Claim DLPDU (CLM)	–	–
6.5.1	General	YES	–
6.5.2	Structure of CLM DLPDU	YES	–
6.5.3	Parameter of CLM DLPDU	–	–
6.5.3.1	Residual counts of CLM DLPDU parameter (RC)	YES	–
6.5.3.2	Slot time (ST) parameter	YES	Relevant feature to star-architecture
6.5.3.3	Node mode (NM) parameter	NO	–
6.5.4	User data of CLM DLPDU	YES	–
6.5.5	Sending and receiving CLM DLPDU	YES	–
6.6	Command DLPDU (COM)	YES	–
6.6.1	General	YES	–
6.6.2	Structure of COM DLPDU	YES	–
6.6.3	Parameter of COM DLPDU	YES	–
6.6.4.	User data of COM DLPDU	YES	–
6.6.5	Sending and receiving COM DLPDU	YES	Relevant feature to star-architecture
6.7	Cyclic data and cyclic data with transmission complete DLPDU (DT) and (DT-CMP)	–	–
6.7.1	General	YES	–
6.7.2	Structure of the DT DLPDU	YES	–
6.7.3	Parameters of DT DLPDU	–	–
6.7.3.1	DLCEP-address parameter	YES	–
6.7.3.2	Word length parameter (WD)	–	–
6.7.3.2.1	WD for star-architecture	YES	–
6.7.3.2.2	WD for loop-architecture	NO	–
6.7.4	Sending DT or DT-CMP DLPDU	YES	–
6.7.5	Receiving DT or DT-CMP DLPDU	YES	–
6.8	RAS DLPDU (RAS)	–	–
6.8.1	General	YES	–
6.8.2	Structure of RAS DLPDU	YES	–
6.8.3	DCEP-address parameters	YES	–
6.8.4	User data	YES	–
6.8.5	Sending and receiving RAS DLPDU	YES	Relevant feature to star-architecture
6.9	Loop repeat request DLPDU (LRR)	NO	–
6.10	Loop diagnosis DLPDU (LPD)	NO	–

12.2.3 Application layer

12.2.3.1 AL service selection

Table 111 specifies the AL service selection within IEC 61158-5-11.

In addition AL services are mapped onto the TCP/UDP/IP protocol suite, as defined in RFC 793, RFC 768 and RFC 791 respectively.

Table 111 – CP 11/1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	Relevant reference only
3	Terms and definitions, abbreviations and conventions	Partial	Used when applicable
4	Concepts	YES	–
5	Data type ASE	Partial	Used when applicable
6	Communication model specification	YES	–

12.2.3.2 AL protocol selection

Table 112 specifies the AL protocol selection within IEC 61158-6-11.

Table 112 – CP 11/1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative reference	Partial	Relevant reference only
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	FAL Syntax description	YES	–
5	Transfer syntax	YES	–
6	FAL protocol state machine structures	YES	–
7	FAL Service Protocol Machine (FSPM)	YES	–
8	Application Relationship Protocol Machines (ARPM)	YES	–
9	DLL Mapping Protocol Machines (DMPM)	YES	–

12.2.4 Performance indicator selection

12.2.4.1 Performance indicator overview

Table 113 shows the performance indicators overview of CP 11/1.

Table 113 – CP 11/1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	Star topology
Number of switches between end-stations	NO	Hubs fit, and switches should not be applicable for highest performance
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	IEC 61588 shall be installed
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	YES	Null time switching without interruption

12.2.4.2 Performance indicator dependencies

12.2.4.2.1 Dependency matrix

Table 114 shows the dependencies between performance indicators for CP 11/1.

Table 114 – CP 11/1: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchron. accuracy	non time- based synchron. accuracy	Redundancy recovery time
Delivery time		NO 12.2.4.2.2 12.2.4.2.4	NO 12.2.4.2.5	NO 12.2.4.2.2 12.2.4.2.3	NO 12.2.4.2.2 12.2.4.2.3	NO	NO	NO 12.2.4.2.6
Number of end-stations	NO		NO	YES 12.2.4.2.2 12.2.4.2.3	YES 12.2.4.2.2 12.2.4.2.3	NO	NO	NO
Basic network topology	NO	NO		NO	NO	NO	NO	NO
Throughput RTE	YES 12.2.4.2.2 12.2.4.2.3	YES 12.2.4.2.2 12.2.4.2.3	NO		YES 12.2.4.2.2 12.2.4.2.3	NO	NO	NO
Non-RTE bandwidth	YES 12.2.4.2.2 12.2.4.2.3	YES 12.2.4.2.2 12.2.4.2.3	NO	YES 12.2.4.2.2 12.2.4.2.3		NO	NO	NO
Time synchronization accuracy	NO	NO	NO	NO	NO		NO	NO
Non-time-based synchronization accuracy	NO	NO	NO	NO	NO	NO		NO
Redundancy recovery time	NO	NO	NO	NO	NO	NO	NO	

12.2.4.2.2 Calculation of Delivery time

Delivery time is definitely specified by the application users using the TCC data service, and the delivery time specified meets both cases of no transmission error and one lost frame with recovery.

The TCC data service provides 3 kinds of the data transmission service at the same time, that are according to the data preference and the delivery time of an APDU to be transferred using the data transmission service.

Table 115 specifies the TCC data service selection supported by this profile.

Table 115 – CP 11/1: TCC data service selection

Service ref.	Service name	Applicable	Constraint
IEC 61158-3-11 Clause 4	High-speed cyclic data transmission	YES	The range of the high-speed transmission period (T_h) is 1 to 160 ms, of which unit is in 0,1 ms
IEC 61158-3-11 Clause 4	Medium-speed cyclic data transmission	YES	The range of the medium-speed transmission period (T_m) is 10 to 1 000 ms, of which unit is in 1 ms and in multiples of the T_h
IEC 61158-3-11 Clause 4	Low-speed cyclic data transmission	YES	The range of low-speed transmission period (T_l) is 100 to 10 000 ms, of which unit is in 1 ms and in multiples of the T_h

The performance indicator delivery time is related to the amount of both RTE data and non-RTE data which are exchanged between the end-stations, the number of the Ethernet frame that is used for the deterministic transmission scheduling, the signal propagation delay to the end-station, the number of the end-stations and the number of the Hubs between the end-stations.

The performance indicator delivery time can be calculated using the Formulae (28), (29), (30), (31) and (32).

$$DT_H = T_h \tag{28}$$

$$DT_M = T_m \tag{29}$$

$$DT_L = T_l \tag{30}$$

$$T_h = T_{RTE} + T_{NRT} + T_{SCH} + T_{PD} + T_{MAC} \tag{31}$$

$$T_{RTE} = T_{HS} + \frac{T_{MS}}{T_m} \times T_h + \frac{T_{LS}}{T_l} \times T_h \tag{32}$$

where

DT_H	is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_M	is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_L	is the delivery time for the low-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
T_h	is the high-speed transmission time period, and is the basic cycle_time (ct) for the TCC data service;
T_m	is the medium-speed transmission time period;

T_l	is the low-speed transmission time period;
T_{RTE}	is the total sum of the frame transmit time, in which the frame of the Ethernet with the RTE data as a payload of a fixed length is sent out of the end-station within the time period of T_h. The total volume of the RTE data and the bandwidth for the non-RTE data is specified by the application user;
T_{NRT}	is the total sum of the frame transmit time, in which the frame with the non-RTE data as a payload is sent out of the end-station within the time period of T_h and is used for the standard Ethernet application on sporadic basis;
T_{SCH}	is the total sum of the frame transmit time, in which the frame is exchanged for the deterministic transmission scheduling between the end-stations. The T_{SCH} includes both the time for the synchronization DLPDU and the multiple Transmission complete DLPDUs which are specified in the IEC 61158-4-11, Clause 6;
T_{PD}	is the sum total of the signal propagation delay (pd) between the end-stations. The T_{PD} depends on the number of Hubs between the end-stations, the cable propagation delay (cd) and the number of the end-stations;
T_{MAC}	is the time for the maintenance and control, in which a new end-station is solicited to join and the periodic time operation is controlled;
T_{HS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the high-speed cyclic data;
T_{MS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the medium-speed cyclic data;
T_{LS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the low-speed cyclic data.

12.2.4.2.3 Relation between throughput RTE and non-RTE bandwidth

Figure 9 shows an example of the relation between the throughput RTE and the non-RTE bandwidth in the case of 100 Mbit/s physical layer. This profile supports the specification of a percentage of the bandwidth and/or the throughput which are used for the non-RTE and the RTE communications.

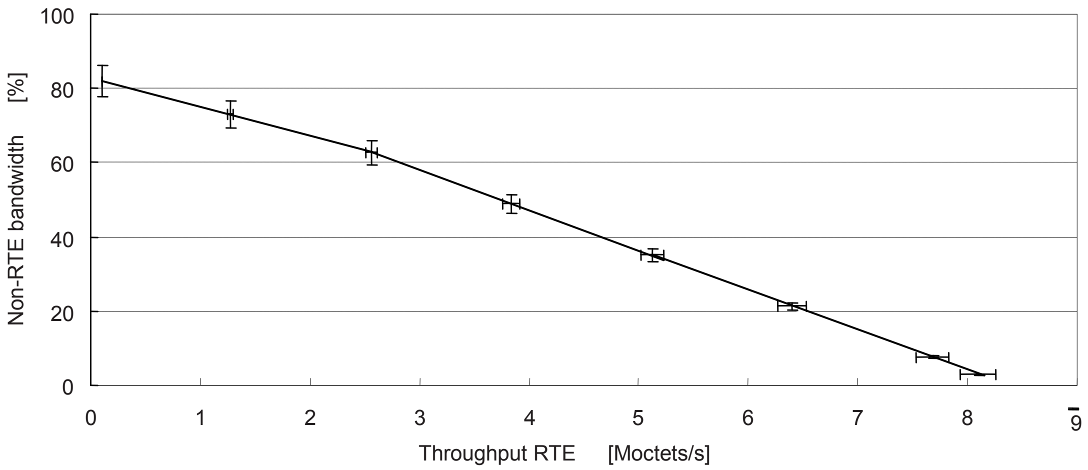

Figure 9 – CP 11/1: Throughput RTE and non-RTE bandwidth

The throughput RTE indicates the total amount of the APDU data by octet length per second, and the APDU data is sent out by the node using the TCC data service specified in the IEC 61158-3-11, 4.3. The non-RTE bandwidth indicates the total percentage of the bandwidth, which is used for the non-RTE communications by the nodes using the sporadic message data service specified in the IEC 61158-3-11, 4.4.

The total bandwidth can be calculated using the Formulae (33), (34), (35), (36), (37) and (38).

$$BW = BW_{RTE} + BW_{NRT} + BW_{CNT} \tag{33}$$

$$BW_{RTE} = TR_{RTE} \times \frac{8}{100} \tag{34}$$

$$TR_{RTE} = TR_{HS} + TR_{MS} + TR_{LS} \tag{35}$$

$$TR_{HS} = \frac{DV_{HS}}{DT_H} \tag{36}$$

$$TR_{MS} = \frac{DV_{MS}}{DT_M} \tag{37}$$

$$TR_{LS} = \frac{DV_{LS}}{DT_L} \tag{38}$$

where

BW	is the total bandwidth in %, and the 100 % is 100 Mbit/s;
BW_{RTE}	is the bandwidth used for the RTE communications in %;
BW_{NRT}	is the bandwidth used for the non-RTE communications in %;
BW_{CNT}	is the bandwidth used for the scheduling communications and for the protocol overhead in %;
TR_{RTE}	is the throughput RTE in Moctets/s;
TR_{HS}	is the throughput RTE for the high-speed cyclic data in Moctets/s;
TR_{MS}	is the throughput RTE for the medium-speed cyclic data in Moctets/s;
TR_{LS}	is the throughput RTE for the low-speed cyclic data in Moctets/s;
DV_{HS}	is the total volume of the high-speed cyclic data sent by all end-stations;
DV_{MS}	is the total volume of the medium-speed cyclic data sent by all end-stations;
DV_{LS}	is the total volume of the low-speed cyclic data sent by all end-stations;
DT_{H}	is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_{M}	is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_{L}	is the delivery time for the low-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC.

The throughput RTE or the non-RTE bandwidth depends on the $\mathrm{BW}_{\mathrm{CNT}}$ for scheduling the communications and for the protocol overhead. The scheduling communications and the protocol overhead, based on the formulas provided in 12.2.4.2.2, depend on the number of the hubs between the end-stations, the cable propagation delay and the total number of the end-stations, and is related to the time for the maintenance and control in order to solicit a new end-stations and to keep the periodic time operation.

12.2.4.2.4 Number of end-stations

The maximum number of the end-stations shall be up to 254.

12.2.4.2.5 Basic network topology

The network topology supported by this profile is of a hierarchical star. The number of layers in a hierarchy is an application specific and is determined on the basis of the number of end-stations, their physical location, and the distance between the end-stations. The maximum number of hubs between any 2 end-stations shall be up to 7.

12.2.4.2.6 Redundancy recovery time

The maximum time from a failure to become fully operational again in case of a single permanent failure, is almost 0 time period. This profile supports fully operational without the interruption of the higher-level data transfer services.

12.2.4.3 Consistent set of performance indicators

12.2.4.3.1 Consistent set of PIs preferential for RTE communications

Table 116 shows one of a consistent set of the performance indicators for CP 11/1. The values in Table 116 are representing one of the practical example, but not of the theoretical maximum, and the example is preferential for the RTE communications, which means that the total available bandwidth both for the RTE communications and the non-RTE communications is allocated alone to the RTE communications.

Table 116 – CP 11/1: Consistent set of PIs preferential for RTE communications

Performance indicator	Value	Constraints
Delivery time	DT_H = 2 ms DT_M = 20 ms DT_L = 200 ms	–
Number of end-stations	24	Maximum distance between nodes is 4 km
Number of switches between end-stations	0	3 hubs
Throughput RTE	Total = 7,3 Moctets/s TR_{HS} = 6,4 Moctets/s TR_{MS} = 0,9 Moctets/s	DV_{HS} = 12 800 octets DV_{MS} = 19 200 octets DV_L = 0 octets
Non-RTE bandwidth	0 %	–
Non-time-based synchronization accuracy	< 10 µs	–
Redundancy recovery time	0 s	–

12.2.4.3.2 Consistent set of PIs for RTE and non-RTE communications

Table 117 shows one consistent set of performance indicators for CP 11/1. The values given in Table 117 are representing one practical example, but they are not the theoretical maximum. The total available bandwidth is partitioned between the RTE communications and the non-RTE communications.

Table 117 – CP 11/1: Consistent set of PIs both for RTE and non-RTE communications

Performance indicator	Value	Constraints
Delivery time	DT_H = 2 ms DT_M = 20 ms DT_L = 200 ms	–
Number of end-stations	13	Maximum distance between nodes is 4 km
Number of switches between end-stations	0	5 hubs
Throughput RTE	Total = 5,7 Moctets/s TR_{HS} = 5,1 Moctets/s TR_{MS} = 0,6 Moctets/s	DV_{HS} = 10 240 octets DV_{MS} = 12 800 octets DV_L = 0 octets
Non-RTE bandwidth	< 20 %	–
Non-time-based synchronization accuracy	< 10 µs	–
Redundancy recovery time	0 s	–

12.3 Profile 11/2

12.3.1 Physical layer

The physical layer of 100 Mbit/s shall be according to ISO/IEC 8802-3.

Connectors and cables are specified in IEC 61784-5-11 and IEC 61918.

12.3.2 Data-link layer

12.3.2.1 DLL services selection

The DLL service selection is the same as specified in 12.2.2.1.

12.3.2.2 DLL protocol selection

Table 118 specifies the DLL protocol selection within IEC 61158-4-11.

Table 118 – CP 11/2: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	Relevant reference only
3	Terms, definitions, symbols and abbreviations	Partial	–
4	Overview of the DL-protocol	–	–
4.1	General	YES	–
4.2	Overview of the medium access control	YES	–
4.3	Service assumed from the PhL	YES	–
4.4	DLL architecture	–	–
4.4.1	Overview	YES	–
4.4.2	Star-architecture	NO	–
4.4.3	Loop-architecture	YES	–
4.5	Access control machine and schedule support functions	YES	–

Clause	Header	Presence	Constraints
4.6	Local parameters, variables, counters, timers and queues	–	–
4.6.1	Overview	YES	–
4.6.1.1	General	YES	–
4.6.1.2	Summary of variables, parameters, counters, timers for star-architecture	NO	–
4.6.1.3	Summary of variables, parameters, counters, timers for loop-architecture	YES	Relevant values and features to 100 Mbit/s data rate
4.6.2	Type 11 common variables, parameters, counters, timers and queues	YES	Relevant values and features to 100 Mbit/s data rate
4.6.3	Star-architecture specific variables, parameters counters timers and queues	NO	–
4.6.4	Loop-architecture specific variables, parameters, counters timers and queues	YES	Relevant values and features to 100 Mbit/s data rate
5	General structure and encoding of PhIDEs and DLPDU and related element of procedure	YES	See Table 119
6	DLPDU-specific structure, encoding and elements of procedure	YES	See Table 120
7	DLE element of procedure	–	–
7.1	DLE elements of procedure for star-architecture	NO	–
7.2	DLE elements of procedure for loop-architecture	–	–
7.2.1	Overall structure	YES	–
7.2.2	Initialization	YES	–
7.2.3	Cyclic transmission TX/RX control (CTRC)	YES	Relevant values and features to 100 Mbit/s data rate
7.2.4	Sporadic TX/RX control (STRC)	YES	–
7.2.5	Access control machine (ACM)	YES	Table 75 applicable
7.2.6	Redundancy medium control (RMC)	YES	Table 83 applicable
7.3	Serializer and deserializer	YES	–
7.4	DLL management protocol	–	–
7.4.1	DLL management protocol for star-architecture	NO	–
7.4.2	DLL management protocol for loop-architecture	YES	–

Table 119 – CP 11/2: DLL protocol selection of Clause 5

Clause	Header	Presence	Constraints
5.1	Overview	YES	–
5.2	PhIDU structure and encoding	YES	–
5.3	Common MAC frame structure, encoding and elements of procedure	YES	–
5.4	Elements of the MAC frame	–	–
5.4.1	General	YES	–
5.4.2	Preamble field	YES	–
5.4.3	Start frame delimiter (SFD)	YES	–
5.4.4	Address field	YES	–
5.4.5	Length/type field	YES	–
5.4.6	Frame control field (FC)	–	–
5.4.6.1	Structure of FC field	YES	–
5.4.6.2	Frame type (F-type) field	YES	–
5.4.6.3	Priority field (Pri)	YES	Relevant feature to 100 Mbit/s data rate
5.4.7	Source node number field (SN)	YES	–
5.4.8	Data and pad field	YES	–
5.4.9	Frame check sequence (FCS)	YES	–
5.5	Order of bit transmission	YES	–
5.6	Invalid DLPDU	YES	–

Table 120 – CP 11/2: DLL protocol selection of Clause 6

Clause	Header	Presence	Constraints
6.1	General	YES	–
6.2	Synchronization DLPDU (SYN)	–	–
6.2.1	General	YES	–
6.2.2	Structure of SYN DLPDU	YES	–
6.2.3	Parameters of SYN DLPDU	–	–
6.2.3.1	Transmission permits node number (PN)	YES	Relevant feature to 100 Mbit/s operation of loop architecture
6.2.3.2	Control word (CW)	–	–
6.2.3.2.1	CW for star-architecture	NO	–
6.2.3.2.2	CW for loop-architecture	YES	–
6.2.3.3	Slot time (ST)	YES	Relevant feature to 100 Mbit/s operation of loop architecture
6.2.3.4	High-speed transmission period (Th)	YES	–
6.2.3.5	Medium-speed transmission period (Tm)	YES	–
6.2.3.6	Sporadic message transmission target-token-rotation-time period (Ts)	NO	Relevant feature to 100 Mbit/s operation of loop architecture
6.2.3.7	Low-speed transmission period (Tl)	NO	–
6.2.3.8	Live list (LL)	YES	–
6.2.4	User data	YES	–

Clause	Header	Presence	Constraints
6.2.5	Sending SYN DLPDU	YES	–
6.2.6	Receiving SYN DLPDU	YES	–
6.3	Transmission complete DLPDU (CMP)	YES	Relevant feature to 100 Mbit/s operation of loop architecture
6.4	In-ring request DLPDU (REQ)	–	–
6.4.1	General	YES	–
6.4.2	Structure of REQ DLPDU	YES	–
6.4.3	Node mode – ESYN Parameter	NO	–
6.4.4	Recipient node number (RN) Paramete	YES	–
6.4.5	User data of REQ DLPDU	YES	–
6.4.6	Sending REQ DLPDU	YES	Relevant feature to 100 Mbit/s operation of loop architecture
6.4.7	Receiving REQ DLPDU	YES	–
6.5	Claim DLPDU (CLM)	–	–
6.5.1	General	YES	–
6.5.2	Structure of CLM DLPDU	YES	–
6.5.3	Parameter of CLM DLPDU	–	–
6.5.3.1	Residual counts of CLM DLPDU parameter (RC)	YES	–
6.5.3.2	Slot time (ST) parameter	YES	Relevant feature to 100 Mbit/s operation of loop-architecture
6.5.3.3	Node mode (NM) parameter	NO	–
6.5.4	User data of CLM DLPDU	YES	–
6.5.5	Sending and receiving CLM DLPDU	YES	–
6.6	Command DLPDU (COM)	–	–
6.6.1	General	YES	–
6.6.2	Structure of COM DLPDU	YES	–
6.6.3	Parameter of COM DLPDU	YES	–
6.6.4	User data of COM DLPDU	YES	–
6.6.5	Sending and receiving COM DLPDU	YES	Relevant feature to 100 Mbit/s operation of loop-architecture
6.7	Cyclic data and cyclic data with transmission complete DLPDU (DT) and (DT-CMP)	–	–
6.7.1	General	YES	–
6.7.2	Structure of the DT DLPDU	YES	–
6.7.3	Parameters of DT DLPDU	YES	–
6.7.3.1	DLCEP-address parameter	YES	–
6.7.3.2	Word length parameter (WD)	–	–
6.7.3.2.1	WD for star-architecture	NO	–
6.7.3.2.2	WD for loop-architecture	YES	Relevant feature to 100 Mbit/s operation of loop-architecture
6.7.4	Sending DT or DT-CMP DLPDU	YES	–
6.7.5	Receiving DT or DT-CMP DLPDU	YES	–
6.8	RAS DLPDU (RAS)	YES	–

Clause	Header	Presence	Constraints
6.8.1	General	–	–
6.8.2	Structure of RAS DLPDU	YES	–
6.8.3	DCEP-address parameters	YES	–
6.8.4	User data	YES	–
6.8.5	Sending and receiving RAS DLPDU	YES	Relevant feature to 100 Mbit/s operation of loop-architecture
6.9	Loop repeat request DLPDU (LRR)	YES	–
6.10	Loop diagnosis DLPDU (LPD)	YES	–

12.3.3 Application layer

12.3.3.1 AL service selection

The AL service selection is the same as specified in 12.2.3.1.

12.3.3.2 AL protocol selection

The AL protocol selection is the same as specified in 12.2.3.2.

12.3.4 Performance indicator selection

12.3.4.1 Performance indicator overview

Table 121 shows the performance indicators overview of CP 11/2.

Table 121 – CP 11/2: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end stations	YES	–
Basic network topology	YES	Loop (ring) topology
Number of switches between end stations	NO	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	IEC 61588 shall be installed
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	YES	4 x Th

12.3.4.2 Performance indicator dependencies

12.3.4.2.1 Dependency matrix

Table 122 shows the dependencies between performance indicators for CP 11/2.

Table 122 – CP 11/2: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchron. accuracy	non time- based synchron. accuracy	Redundancy recovery time
Delivery time		NO 12.3.4.2.2 12.3.4.2.3	NO 12.2.4.2.5	NO 12.3.4.2.2 12.3.4.2.3	NO 12.3.4.2.2 12.3.4.2.3	NO	NO	NO 12.3.4.2.6
Number of end stations	NO		NO	YES 12.3.4.2.2 12.3.4.2.3	YES 12.3.4.2.2 12.3.4.2.3	NO	NO	NO
Basic network topology	NO	NO		NO	NO	NO	NO	NO
Throughput RTE	YES 12.3.4.2.2 12.3.4.2.3	YES 12.3.4.2.2 12.3.4.2.3	NO		YES 12.3.4.2.2 12.3.4.2.3	NO	NO	NO
Non-RTE bandwidth	YES 12.3.4.2.2 12.3.4.2.3	YES 12.3.4.2.2 12.3.4.2.3	NO	YES 12.3.4.2.2 12.3.4.2.3		NO	NO	NO
Time synchronization accuracy	NO	NO	NO	NO	NO		NO	NO
Non-time-based synchronization accuracy	NO	NO	NO	NO	NO	NO		NO
Redundancy recovery time	YES 12.3.4.2.6	NO	NO	NO	NO	NO	NO	

12.3.4.2.2 Calculation of Delivery time

Delivery time is definitely specified by the application users using the TCC data service, and the delivery time specified meets both cases of no transmission error and one lost frame with recovery.

The TCC data service provides 2 kinds of data transmission services at the same time, that are according to the data preference and the delivery time of the APDU to be transferred using the data transmission service.

Table 123 specifies the TCC data service selection supported by this profile.

Table 123 – CP 11/2: TCC data service selection

Service ref.	Service name	Applicable	Constraint
IEC 61158-3-11 Clause 4	High-speed cyclic data transmission	YES	The range of the high-speed transmission period (T_h) is 1 to 160 ms, of which unit is in 0,1 ms
IEC 61158-3-11 Clause 4	Medium-speed cyclic data transmission	YES	The range of the medium-speed transmission period (T_m) is 10 to 1 000 ms, of which unit is in 1 ms and in multiples of the T_h

The performance indicator delivery time is related to the amount of both RTE data and non-RTE data which are exchanged between the end stations, the number of the Ethernet frame that is used for the deterministic transmission scheduling, the signal propagation delay to the end station and the number of end stations.

The performance indicator delivery time can be calculated using the Formulae (39), (40), (41) and (42).

$$DT_H = T_h \tag{39}$$

$$DT_M = T_m \tag{40}$$

$$T_h = T_{RTE} + T_{NRT} + T_{SCH} + T_{PD} + T_{MAC} \tag{41}$$

$$T_{RTE} = T_{HS} + \frac{T_{MS}}{T_m} \times T_h \tag{42}$$

where

DT_H	is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_M	is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
T_h	is the high-speed transmission time period, and is the basic cycle_time (ct) for the TCC data service;
T_m	is the medium-speed transmission time period;
T_{RTE}	is the total sum of the frame transmit time, in which the frame of the Ethernet with the RTE data as a payload of a fixed length is sent out of the end station within the time period of T_h. The total volume of the RTE data and the bandwidth for the non-RTE data is specified by the application user;
T_{NRT}	is the total sum of the frame transmit time, in which the frame with the non-RTE data as a payload is sent out of the end station within the time period of T_h and is used for the standard Ethernet application on sporadic basis;
T_{SCH}	is the total sum of the frame transmit time, in which the frame is exchanged for the deterministic transmission scheduling between the end stations. The T_{SCH} includes both the time for the synchronization DLPDU and the multiple Transmission complete DLPDUs which are specified in the IEC 61158-4-11, Clause 6;
T_{PD}	is the sum total of the signal propagation delay (pd) between the end stations. The T_{PD} depends on the cable propagation delay (cd) and the number of the end stations;
T_{MAC}	is the time for the maintenance and control, in which a new end station is solicited to join and the periodic time operation is controlled;
T_{HS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the high-speed cyclic data;
T_{MS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the medium-speed cyclic data.

12.3.4.2.3 Relation between throughput RTE and non-RTE bandwidth

Figure 10 shows an example of the relation between the throughput RTE and the non-RTE bandwidth in the case of a 100 Mbit/s physical layer. This profile supports the specification of a percentage of the bandwidth and/or the throughput which are used for the non-RTE and the RTE communications.

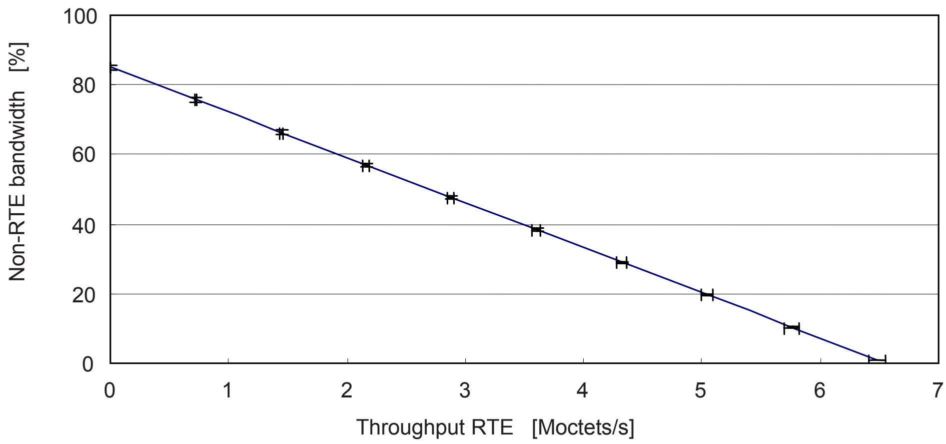

Figure 10 – CP 11/2: Throughput RTE and non-RTE bandwidth

The throughput RTE indicates the total amount of the APDU data by octet length per second, and the APDU data is sent out by the node using the TCC data service specified in IEC 61158-3-11, 4.3. The non-RTE bandwidth indicates the total percentage of the bandwidth, which is used for the non-RTE communications by the nodes using the sporadic message data service specified in the IEC 61158-3-11, 4.4.

The total bandwidth can be calculated using the Formulae (43), (44), (45), (46) and (47).

$$BW = BW_{RTE} + BW_{NRT} + BW_{CNT} \tag{43}$$

$$BW_{RTE} = TR_{RTE} \times \frac{8}{100} \tag{44}$$

$$TR_{RTE} = TR_{HS} + TR_{MS} \tag{45}$$

$$TR_{HS} = \frac{DV_{HS}}{DT_H} \tag{46}$$

$$TR_{MS} = \frac{DV_{MS}}{DT_M} \tag{47}$$

where

BW is the total bandwidth in %, and the 100 % is 100 Mbit/s;
BW_{RTE} is the bandwidth used for the RTE communications in %;
BW_{NRT} is the bandwidth used for the non-RTE communications in %;
BW_{CNT} is the bandwidth used for the scheduling communications and for the protocol overhead in %;
TR_{RTE} is the throughput RTE in Moctets/s;
TR_{HS} is the throughput RTE for the high-speed cyclic data in Moctets/s;
TR_{MS} is the throughput RTE for the medium-speed cyclic data in Moctets/s;
DV_{HS} is the total volume of the high-speed cyclic data sent by all end stations;
DV_{MS} is the total volume of the medium-speed cyclic data sent by all end stations;
DT_H is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_M is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;

The throughput RTE or the non-RTE bandwidth depends on the BW_{CNT} for scheduling the communications and for the protocol overhead. The scheduling communications and the protocol overhead, based on the formulae provided in 12.3.4.2.2, depend on the cable propagation delay and the total number of the end stations and is related to the time for the maintenance and control in order to solicit a new end station and to keep the periodic time operation.

12.3.4.2.4 Number of end-station

The maximum number of end stations shall be up to 254.

12.3.4.2.5 Basic network topology

The network topology supported by this profile is of a loop (ring).

12.3.4.2.6 Redundancy recovery time

The maximum time from a failure to become fully operational again in case of a single permanent failure is 4 x T_h (T_h: the high-speed transmission time period) in 12.3.4.2.2.

12.3.4.3 Consistent set of performance indicators

12.3.4.3.1 Consistent set of PIs preferential for RTE communications

Table 124 shows one of a consistent set of the performance indicators for CP 11/2. The values in Table 124 are representing one practical example, but not the theoretical maximum. The example is preferential for RTE communications, which means that the total available bandwidth both for the RTE communications and the non-RTE communications is allocated alone to the RTE communications.

Table 124 – CP 11/2: Consistent set of PIs preferential for RTE communications

Performance indicator	Value	Constraints
Delivery time	DT_H = 2 ms DT_M = 20 ms	–
Number of end stations	24	Total length of cables in a loop is 2 km
Number of switches between end stations	0	Not applicable
Throughput RTE	Total = 4,6 Moctets/s TR_{HS} = 4,0 Moctets/s TR_{MS} = 0,6 Moctets/s	DV_{HS} = 7 920 octets DV_{MS} = 11 520 octets
Non-RTE bandwidth	0 %	–
Non-time-based synchronization accuracy	< 10 µs	–
Redundancy recovery time	8 ms	–

12.3.4.3.2 Consistent set of PIs for RTE and non-RTE communications

Table 125 shows one consistent set of performance indicators for CP 11/2. The values given in Table 125 are representing one practical example, but they are not the theoretical maximum. The total available bandwidth is partitioned between the RTE communications and the non-RTE communications.

Table 125 – CP 11/2: Consistent set of PIs both for RTE and non-RTE communications

Performance indicator	Value	Constraints
Delivery time	DT_H = 2 ms DT_M = 20 ms	–
Number of end stations	13	Total length of cables in a loop is 2 km
Number of switches between end stations	0	Not applicable
Throughput RTE	Total = 4,8 Moctets/s TR_{HS} = 4,3 Moctets/s TR_{MS} = 0,5 Moctets/s	DV_{HS} = 8 640 octets DV_{MS} = 10 080 octets
Non-RTE bandwidth	< 20 %	–
Non-time-based synchronization accuracy	< 10 µs	–
Redundancy recovery time	8 ms	–

12.4 Profile 11/3

12.4.1 Physical layer

The physical layer of 1 000 Mbit/s shall be according to ISO/IEC 8802-3.

Connectors and cables are specified in IEC 61784–5–11 and IEC 61918.

12.4.2 Data-link layer

12.4.2.1 DLL services selection

The DLL service selection is the same as specified in 12.2.2.1.

12.4.2.2 DLL protocol selection

Table 126 specifies the DLL protocol selection within IEC 61158–4–11.

Table 126 – CP 11/3: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	Relevant reference only
3	Terms, definitions, symbols and abbreviations	Partial	–
4	Overview of the DL-protocol	–	–
4.1	General	YES	–
4.2	Overview of the medium access control	YES	–
4.3	Service assumed from the PhL	YES	–
4.4	DLL architecture	–	–
4.4.1	Overview	YES	–
4.4.2	Star-architecture	NO	–
4.4.3	Loop-architecture	YES	–
4.5	Access control machine and schedule support functions	YES	–
4.6	Local parameters, variables, counters, timers and queues	–	–

Clause	Header	Presence	Constraints
4.6.1	Overview	YES	–
4.6.1.1	General	YES	–
4.6.1.2	Summary of variables, parameters, counters, timers for star-architecture	NO	–
4.6.1.3	Summary of variables, parameters, counters, timers for loop-architecture	YES	Relevant values and features to 1 000 Mbit/s data rate
4.6.2	Type 11 common variables, parameters, counters, timers and queues	YES	Relevant values and features to 1 000 Mbit/s data rate
4.6.3	Star-architecture specific variables, parameters counters timers and queues	NO	–
4.6.4	Loop-architecture specific variables, parameters, counters timers and queues	YES	Relevant values and features to 1 000 Mbit/s data rate
5	General structure and encoding of PhIDEs and DLPDU and related element of procedure	YES	See Table 127
6	DLPDU-specific structure, encoding and elements of procedure	YES	See Table 128
7	DLE element of procedure	–	–
7.1	DLE elements of procedure for star-architecture	NO	–
7.2	DLE elements of procedure for loop-architecture	–	–
7.2.1	Overall structure	YES	–
7.2.2	Initialization	YES	–
7.2.3	Cyclic transmission TX/RX control (CTRC)	YES	Relevant values and features to 1 000 Mbit/s data rate
7.2.4	Sporadic TX/RX control (STRC)	YES	–
7.2.5	Access control machine (ACM)	YES	Table 76 applicable
7.2.6	Redundancy medium control (RMC)	YES	Table 84 applicable
7.3	Serializer and deserializer	YES	–
7.4	DLL management protocol	–	–
7.4.1	DLL management protocol for star-architecture	NO	–
7.4.2	DLL management protocol for loop-architecture	YES	–

Table 127 – CP 11/3: DLL protocol selection of Clause 5

Clause	Header	Presence	Constraints
5.1	Overview	YES	–
5.2	PhIDU structure and encoding	YES	–
5.3	Common MAC frame structure, encoding and elements of procedure	YES	–
5.4	Elements of the MAC frame	–	–
5.4.1	General	YES	–
5.4.2	Preamble field	YES	–
5.4.3	Start frame delimiter (SFD)	YES	–
5.4.4	Address field	YES	–
5.4.5	Length/type field	YES	–
5.4.6	Frame control field (FC)	–	–
5.4.6.1	Structure of FC field	YES	–
5.4.6.2	Frame type (F-type) field	YES	–

Clause	Header	Presence	Constraints
5.4.6.3	Priority field (Pri)	YES	Relevent feature to 1 000 Mbit/s data rate
5.4.7	Source node number field (SN)	YES	–
5.4.8	Data and pad field	YES	–
5.4.9	Frame check sequence (FCS)	YES	–
5.5	Order of bit transmission	YES	–
5.6	Invalid DLPDU	YES	–

Table 128 – CP 11/3: DLL protocol selection of Clause 6

Clause	Header	Presence	Constraints
6.1	General	YES	–
6.2	Synchronization DLPDU (SYN)	–	–
6.2.1	General	YES	–
6.2.2	Structure of SYN DLPDU	YES	–
6.2.3	Parameters of SYN DLPDU	–	–
6.2.3.1	Transmission permits node number (PN)	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.2.3.2	Control word (CW)	–	–
6.2.3.2.1	CW for star-architecture	NO	–
6.2.3.2.2	CW for loop-architecture	YES	–
6.2.3.3	Slot time (ST)	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.2.3.4	High-speed transmission period (Th)	YES	–
6.2.3.5	Medium-speed transmission period (Tm)	YES	–
6.2.3.6	Sporadic message transmission target-token-rotation-time period (Ts)	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.2.3.7	Low-speed transmission period (Tl)	YES	–
6.2.3.8	Live list (LL)	YES	–
6.2.4	User data	YES	–
6.2.5	Sending SYN DLPDU	YES	–
6.2.6	Receiving SYN DLPDU	YES	–
6.3	Transmission complete DLPDU (CMP)	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.4	In-ring request DLPDU (REQ)	–	–
6.4.1	General	YES	–
6.4.2	Structure of REQ DLPDU	YES	–
6.4.3	Node mode – ESYN parameter	YES	–
6.4.4	Recipient node number (RN) parameter	YES	–
6.4.5	User data of REQ DLPDU	YES	–
6.4.6	Sending REQ DLPDU	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.4.7	Receiving REQ DLPDU	YES	–

Clause	Header	Presence	Constraints
6.5	Claim DLPDU (CLM)	–	–
6.5.1	General	YES	–
6.5.2	Structure of CLM DLPDU	YES	–
6.5.3	Parameter of CLM DLPDU	–	–
6.5.3.1	Residual counts of CLM DLPDU parameter (RC)	YES	
6.5.3.2	Slot time (ST) parameter	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.5.3.3	Node mode (NM) parameter	YES	–
6.5.4	User data of CLM DLPDU	YES	–
6.5.5	Sending and receiving CLM DLPDU	YES	–
6.6	Command DLPDU (COM)	–	–
6.6.1	General	YES	–
6.6.2	Structure of COM DLPDU	YES	–
6.6.3	Parameter of COM DLPDU	YES	–
6.6.4	User data of COM DLPDU	YES	–
6.6.5	Sending and receiving COM DLPDU	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.7	Cyclic data and cyclic data with transmission complete DLPDU (DT) and (DT-CMP)	–	–
6.7.1	General	YES	–
6.7.2	Structure of the DT DLPDU	YES	–
6.7.3	Parameters of DT DLPDU	YES	–
6.7.3.1	DLCEP-address parameter	YES	–
6.7.3.2	Word length parameter (WD)	–	–
6.7.3.2.1	WD for star-architecture	NO	–
6.7.3.2.2	WD for loop-architecture	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.7.4	Sending DT or DT-CMP DLPDU	YES	–
6.7.5	Receiving DT or DT-CMP DLPDU	YES	–
6.8	RAS DLPDU (RAS)	–	–
6.8.1	General	YES	–
6.8.2	Structure of RAS DLPDU	YES	–
6.8.3	DCEP-address parameters	YES	–
6.8.4	User data	YES	–
6.8.5	Sending and receiving RAS DLPDU	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.9	Loop repeat request DLPDU (LRR)	YES	–
6.10	Loop diagnosis DLPDU (LPD)	YES	–

12.4.3 Application layer

12.4.3.1 AL service selection

The AL service selection is the same as specified in 12.2.3.1.

12.4.3.2 AL protocol selection

The AL protocol selection is the same as specified in 12.2.3.2.

12.4.4 Performance indicator selection

12.4.4.1 Performance indicator overview

Table 129 shows the performance indicators ovewview of CP 11/3.

Table 129 – CP 11/3: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end stations	YES	–
Basic network topology	YES	Loop (ring) topology
Number of switches between end stations	NO	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	IEC 61588 shall be installed
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	YES	4 x Th

12.4.4.2 Performance indicator dependencies

12.4.4.2.1 Dependency matrix

Table 130 shows the dependencies between performance indicators for CP 11/3.

Table 130 – CP 11/3: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchron. accuracy	non time- based synchron. accuracy	Redundancy recovery time
Delivery time		NO 12.4.4.2.2 12.4.4.2.3	NO 12.4.4.2.5	NO 12.4.4.2.2 12.4.4.2.3	NO 12.4.4.2.2 12.4.4.2.3	NO	NO	NO 12.4.4.2.6
Number of end stations	NO		NO	YES 12.4.4.2.2 12.4.4.2.3	YES 12.4.4.2.2 12.4.4.2.3	NO	NO	NO
Basic network topology	NO	NO		NO	NO	NO	NO	NO
Throughput RTE	YES 12.4.4.2.2 12.4.4.2.3	YES 12.4.4.2.2 12.4.4.2.3	NO		YES 12.4.4.2.2 12.4.4.2.3	NO	NO	NO
Non-RTE bandwidth	YES 12.4.4.2.2 12.4.4.2.3	YES 12.4.4.2.2 12.4.4.2.3	NO	YES 12.4.4.2.2 12.4.4.2.3		NO	NO	NO
Time synchronization accuracy	NO	NO	NO	NO	NO		NO	NO
Non-time-based synchronization accuracy	NO	NO	NO	NO	NO	NO		NO
Redundancy recovery time	YES 12.4.4.2.6	NO	NO	NO	NO	NO	NO	

12.4.4.2.2 Calculation of Delivery time

Delivery time is definitely specified by the application users using the TCC data service, and the delivery time specified meets both cases of no transmission error and one lost frame with recovery.

The TCC data service provides 3 kinds of the data transmission service at the same time, that are according to the data preference and the delivery time of an APDU to be transferred using the data transmission service.

Table 131 specifies the TCC data service selection supported by this profile.

Table 131 – CP 11/3: TCC data service selection

Service ref.	Service name	Applicable	Constraint
IEC 61158-3-11 Clause 4	High-speed cyclic data transmission	YES	The range of the high-speed transmission period (T_h) is 0.1 to 160 ms, of which unit is in 0,1 ms
IEC 61158-3-11 Clause 4	Medium-speed cyclic data transmission	YES	The range of the medium-speed transmission period (T_m) is 1 to 1 000 ms, of which unit is in 1 ms and in multiples of the T_h
IEC 61158-3-11 Clause 4	Low-speed cyclic data transmission	YES	The range of low-speed transmission period (T_l) is 1 to 10 000 ms, of which unit is in 1 ms and in multiples of the T_h

The performance indicator delivery time is related to the amount of both RTE data and non-RTE data which are exchanged between the end-stations, the number of the Ethernet frame that is used for the deterministic transmission scheduling, the signal propagation delay to the end-station, the number of the end-staions.

The performance indicator delivery time can be calculated using the Formulae (48), (49), (50), (51) and (52).

$$DT_H = T_h \tag{48}$$

$$DT_M = T_m \tag{49}$$

$$DT_L = T_l \tag{50}$$

$$T_h = T_{RTE} + T_{NRT} + T_{SCH} + T_{PD} + T_{MAC} \tag{51}$$

$$T_{RTE} = T_{HS} + \frac{T_{MS}}{T_m} \times T_h + \frac{T_{LS}}{T_l} \times T_h \tag{52}$$

where

DT_H	is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_M	is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_L	is the delivery time for the low-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
T_h	is the high-speed transmission time period, and is the basic cycle_time (ct) for the TCC data service;
T_m	is the medium-speed transmission time period;
T_l	is the low-speed transmission time period;
T_{RTE}	is the total sum of the frame transmit time, in which the frame of the Ethernet with the RTE data as a payload of a fixed length is sent out of the end-station within the time period of T_h. The total volume of the RTE data and the bandwidth for the non-RTE data is specified by the application user;
T_{NRT}	is the total sum of the frame transmit time, in which the frame with the non-RTE data as a payload is sent out of the end-station within the time period of T_h and is used for the standard Ethernet application on sporadic basis;
T_{SCH}	is the total sum of the frame transmit time, in which the frame is exchanged for the deterministic transmission scheduling between the end-stations. The T_{SCH} includes both the time for the synchronization DLPDU and the multiple Transmission complete DLPDUs which are specified in the IEC 61158-4-11, Clause 6;
T_{PD}	is the sum total of the signal propagation delay (pd) between the end-stations. The T_{PD} depends on the cable propagation delay (cd) and the number of the end-stations;
T_{MAC}	is the time for the maintenance and control, in which a new end-station is solicited to join and the periodic time operation is controlled;
T_{HS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the high-speed cyclic data;
T_{MS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the medium-speed cyclic data;
T_{LS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the low-speed cyclic data.

12.4.4.2.3 Relation between throughput RTE and non-RTE bandwidth

Figure 11 shows an example of the relation between the throughput RTE and the non-RTE bandwidth in the case of 1 000 Mbit/s physical layer. This profile supports the specification of a percentage of the bandwidth and/or the rhtoughput which are used for the non-RTE and the RTE communications.

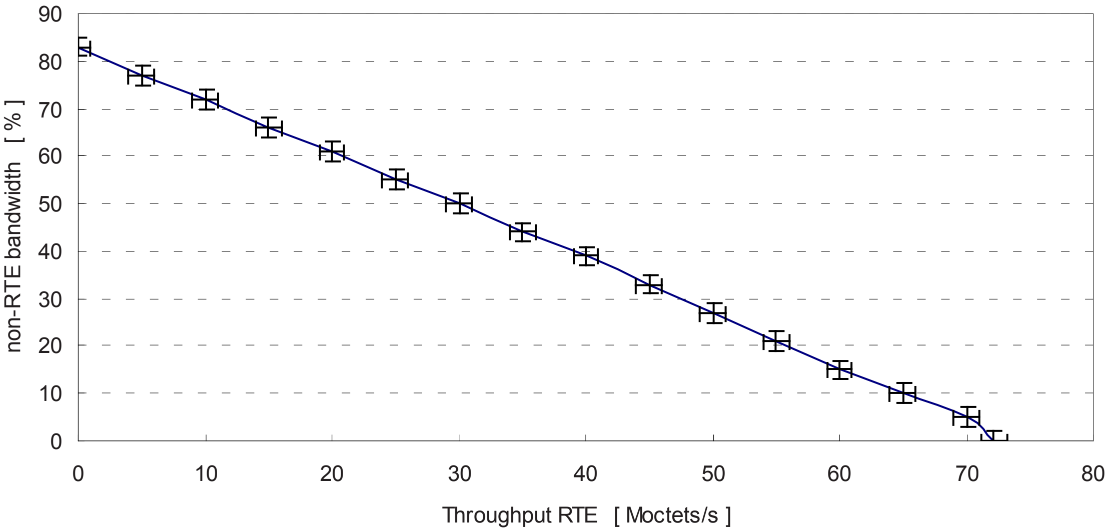

Figure 11 – CP 11/3: Throughput RTE and non-RTE bandwidth

The throughput RTE indicates the total amount of the APDU data by octet length per second, and the APDU data is sent out by the node using the TCC data service specified in the IEC 61158-3-11, 4.3. The non-RTE bandwidth indicates the total percentage of the bandwidth, which is used for the non-RTE communications by the nodes using the sporadic message data service specified in the IEC 61158–3–11, 4.4.

The total bandwidth can be calculated using the Formulae (53), (54), (55), (56), (57) and (58).

$$BW = BW_{RTE} + BW_{NRT} + BW_{CNT} \tag{53}$$

$$BW_{RTE} = TR_{RTE} \times \frac{8}{1000} \tag{54}$$

$$TR_{RTE} = TR_{HS} + TR_{MS} + TR_{LS} \tag{55}$$

$$TR_{HS} = \frac{DV_{HS}}{DT_H} \tag{56}$$

$$TR_{MS} = \frac{DV_{MS}}{DT_M} \tag{57}$$

$$TR_{LS} = \frac{DV_{LS}}{DT_L} \tag{58}$$

where

BW	is the total bandwidth in %, and the 100 % is 1 000 Mbit/s;
BW_{RTE}	is the bandwidth used for the RTE communications in %;
BW_{NRT}	is the bandwidth used for the non-RTE communications in %;
BW_{CNT}	is the bandwidth used for the scheduling communications and for the protocol overhead in %;
TR_{RTE}	is the throughput RTE in Moctets/s;
TR_{HS}	is the throughput RTE for the high-speed cyclic data in Moctets/s;

TR_{MS}	is the throughput RTE for the medium-speed cyclic data in Moctets/s;
TR_{LS}	is the throughput RTE for the low-speed cyclic data in Moctets/s;
DV_{HS}	is the total volume of the high-speed cyclic data sent by all end-stations;
DV_{MS}	is the total volume of the medium-speed cyclic data sent by all end-stations;
DV_{LS}	is the total volume of the low-speed cyclic data sent by all end-stations;
DT_H	is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_M	is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_L	is the delivery time for the low-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC.

The throughput RTE or the non-RTE bandwidth depends on the BW_{CNT} for scheduling the communications and for the protocol overhead. The scheduling communications and the protocol overhead, based on the formulas provided in 12.4.4.2.2, the cable propagation delay and the total number of the end-stations, and is related to the time for the maintenance and control in order to solicit a end-stations and to leep the periodic time operation.

12.4.4.2.4 Number of end station

The maximum number of the end-stations shall be up to 254.

12.4.4.2.5 Basic network topology

The network topology supported by this profile is of a loop (ring).

12.4.4.2.6 Redundancy recovery time

The maximum time from a failure to become fully operational again in case of a single permanent failure is 4 x T_h (T_h: the high-speed transmission time period) in 12.4.4.2.2.

12.4.4.3 Consistent set of performance indicators

12.4.4.3.1 Consistent set of PIs preference for RTE communications

Table 132 shows one of a consistent set of the performance indicators for CP 11/3. The values in Table 132 are representing one of the practical example, but not of the theoretical maximum, and the example is preferential for the RTE communications, which means that the total available bandwidth both for the RTE communications and the non-RTE communications is allocated alone to the RTE communications.

Table 132 – CP 11/3: Consistent set of PIs preferential for RTE communications

Performance indicator	Value	Constraints
Delivery time	DT_H = 1 ms DT_M = 10 ms DT_L = 100 ms	–
Number of end-stations	32	Total length of cables in a loop is 6 km
Number of switches between end-stations	0	Not aaplicable
Throughput RTE	Total = 72,2 Moctets/s TR_{HS} = 59,9 Moctets/s TR_{MS} = 12,0 Moctets/s TR_{LS} = 0,3 Moctets/s	DV_{HS} = 59 904 octets DV_{MS} = 119 808 octets DV_{LS} = 299 520 octets
Non-RTE bandwidth	0 %	–
Non-time-based synchronization accuracy	$< 10\ \mu s$	–
Redundancy recovery time	4 ms	–

12.4.4.3.2 Consistent set of PIs for RTE and non-RTE communications

Table 133 shows one consistent set of performance indicators for CP 11/3. The values given in Table 133 are representing one practical example, but they are not the theoretical maximum. The total available bandwidth is partitioned between the RTE communications and the non-RTE communications.

Table 133 – CP 11/3: Consistent set of PIs both for RTE and non-RTE communications

Performance indicator	Value	Constraints
Delivery time	DT_H = 1 ms DT_M = 10 ms DT_L = 100 ms	–
Number of end-stations	32	Total length of cables in a loop is 6 km
Number of switches between end-stations	0	Not applicable
Throughput RTE	Total = 56,9 Moctets/s TR_{HS} = 48,6 Moctets/s TR_{MS} = 6,4 Moctets/s TR_{LS} = 1,9 Moctets/s	DV_{HS} = 48 640 octets DV_{MS} = 64 000 octets DV_{LS} = 192 000 octets
Non-RTE bandwidth	> 20 %	–
Non-time-based synchronization accuracy	$< 10\ \mu s$	–
Redundancy recovery time	4 ms	–

13 Communication Profile Family 12 (EtherCAT®) – RTE communication profiles

13.1 General overview

EtherCAT® [10] is a Real-Time Ethernet technology based on ISO/IEC 8802-3, IEC 61158-2, IEC 61158-3-12, IEC 61158-4-12, IEC 61158-5-12 and IEC 61158-6-12 especially suitable for communication between control systems and peripheral devices like I/O systems, drives, sensors and actuators.

In this part of IEC 61784, the following communication profiles are specified for CPF 12:

– Profile 12/1

  This profile defines protocol and service selections for simple I/O devices which may communicate process data cyclically.

– Profile 12/2

  This profile defines protocol and service selections for two types of devices:

  - smart or modular devices with mailbox communication capabilities;
  - such devices that additionally support time based synchronization for performing tightly coordinated actions.

All three types of devices can be mixed arbitrarily.

13.2 Profile CP 12/1

13.2.1 Physical layer

The physical layer is described in IEC 61158-2 and IEEE 802.3-2008. Table 134 specifies the use of the preferred physical layer, specified in IEEE 802.3-2008, included in this profile.

Table 135 specifies the use of an optimized physical layer for backplane applications, specified in of IEC 61158-2, included in this profile.

Table 134 – CP 12/1: PhL selection of preferred physical layer from IEEE 802.3-2008

Clause	Header	Presence	Constraints
21	Introduction to 100 Mb/s baseband networks, type 100BASE-T	YES	–
22	Reconciliation Sublayer (RS) and Media Independent Interface (MII)	YES	–
23	Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 100BASE-T4	–	–
24	Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X	YES	–
25	Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-TX	Optional	Preferred technology
26	Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-FX	Optional	Use for specific environmental conditions
27	Repeater for 100 Mb/s baseband networks	–	

[10] EtherCAT® is a registered trade name of Beckhoff, Verl. This information is given for the convenience of users of this document and does not constitute an endorsement by the IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name EtherCAT. Use of the trade name EtherCAT requires permission from the trade name holder.

Clause	Header	Presence	Constraints
28	Physical Layer link signaling for 10 Mb/s, 100 Mb/s, and 1 000 Mb/s Auto-Negotiation on twisted pair	Optional	Auto-negotiation and auto-crossover are highly recommended
29	System considerations for multisegment 100BASE-T networks	Optional	Link aggregation can be used but not recommended
Annex 22A	MII	YES	–
Annex 23A	6T code words	YES	–
34 ff	Introduction to 1 000 Mb/s baseband network	Optional	For future use

Table 135 – CP 12/1: PhL selection of an optimized physical layer from IEC 61158-2

Clause	Header	Presence	Constraints
5	DLL – PhL interface	–	–
5.8	Type 12: Required services	YES	–
6	Systems management – PhL interface	–	–
6.7	Type 12: Systems management – PhL interface	YES	–
7	DCE independent sublayer (DIS)	–	–
7.6	Type 12: DIS	YES	–
8	DTE – DCE interface and MIS-specific functions	–	–
8.5	Type 12: DTE – DCE interface	YES	Interface not exposed
9	Medium dependent sublayer (MDS)	–	–
9.9	Type 12: Wire media	YES	–
10	MDS – MAU interface	–	–
29	Type 12: Medium attachment unit: electrical medium	YES	–

13.2.2 Data-link layer

13.2.2.1 EtherCAT Slave

Data-link layer is described in IEC 61158-3-12 and IEC 61158-4-12. Table 136 specifies the use of the services, specified in IEC 61158-3-12, included in this profile. Table 137 specifies the use of the protocol, specified in IEC 61158-4-12, included in this profile.

Table 136 – CP 12/1: DLL service selection

Clause	Header	Presence	Constraints
4	Data-link layer services and concepts	–	–
4.1	Operating principle	YES	–
4.2	Topology	YES	–
4.3	Data-link layer overview	YES	–
4.4	Error detection overview	YES	–
4.5	Parameter and process data handling introduction	Partial	Some examples are not describing mandatory functions
4.6	Node reference model	YES	–
4.7	Operation overview	Partial	Direct mode mandatory
4.8	Addressing	YES	–
4.9	Slave classification	Partial	Basic slave mandatory
4.10	Structure of the communication layer in the slave	Partial	–
5	Communication services	–	–
5.1	Overview	YES	–
5.2	Read services	Partial	Responder Services (.ind/.rsp)
5.3	Write services	Partial	Responder Services (.ind/.rsp)
5.4	Combined read/write services	Partial	Responder Services (.ind/.rsp)
5.5	Network services	NO	–
5.6	Mailbox	NO	–
6.	Local interactions	–	–
6.1	Read Local	YES	–
6.2	Write Local	YES	–

Table 137 – CP 12/1: DLL protocol selection

Clause	Header	Presence	Constraints
4	Overview of the DL-protocol	–	–
4.1	Operating principle	YES	–
4.2	Topology	YES	–
4.3	Frame processing principles	YES	–
4.4	Data-link layer overview	YES	–
4.5	Error detection overview	YES	–
4.6	Node reference model	YES	–
4.7	Operation overview	Partial	Direct mode mandatory
5	Frame Sructure	–	–
5.1	Frame coding principles	YES	–
5.2	Data types and encoding rules	Partial	Types needed for application and unsigned integer types
5.3	DL PDU structure	YES	–
5.4	Type 12 DLPDU structure	YES	–
5.5	Network variable structure	NO	–
5.6	Type 12 mailbox structure	NO	–
6	Attributes	–	–

Clause	Header	Presence	Constraints
6.1	Management	YES	–
6.2	Statistics	YES	–
6.3	Watchdogs	YES	–
6.4	Slave information interface	YES	–
6.5	Media independent interface (MII)	YES	–
6.6	Fieldbus memory management unit (FMMU)	YES	–
6.7	Sync manager	NO	–
6.8	Distributed Clock	Partial	Timestamping of messages if more than 2 ports
7	DL-user memory	–	
7.1	Overview	Optional	If mailbox supported
7.2	Mailbox access type	Optional	If mailbox supported
7.3	Buffered access type	Optional	–
8	Type 12:FDL Protocol state machines	–	–
8.1	Overview of slave DL state machines	Partial	Machines mandatory
8.2	State machine description	–	–
8.2.1	Port state machine (PSM)	YES	–
8.2.2	PDU handler state machine (DHSM)	YES	–
8.2.3	Synch manager state machine (SYMSM)	YES	–
8.2.4	Resilient Mailbox State Machine (RMSM)	Optional	If mailbox supported
8.2.5	SII State Machine (SIISM)	YES	–
8.2.6	MII State Machine (MIISM)	YES	–
8.2.7	DC State Machine (DCSM)	Partial	Timestamping of messages if more than 2 ports

13.2.2.2 EtherCAT Master

The data-link layer is described in IEC 61158-3-12 and IEC 61158-4-12. Table 138 specifies the use of the services, specified in IEC 61158-3-12, included in this profile.

Table 139 specifies the use of the protocol, specified in IEC 61158-4-12, included in this profile. The selection of services used is up to the master. The Auto Increment Read and Write services are mandatory.

Table 138 – CP 12/1: DLL service selection

Clause	Header	Presence	Constraints
4	Data-link layer services and concepts	–	–
4.1	Operating principle	YES	–
4.2	Topology	YES	–
4.3	Data-link layer overview	YES	–
4.4	Error detection overview	YES	–
4.5	Parameter and process data handling introduction	Partial	Some example are not describing mandatory functions
4.6	Node reference model	YES	–
4.7	Operation overview	Partial	Direct mode mandatory
4.8	Addressing	YES	–
4.9	Slave classification	NO	–
4.10	Structure of the communication layer in the slave	Partial	–
5	Communication services	–	–
5.1	Overview	YES	–
5.2	Read services	Partial	Requestor Services (.req/.cnf)
5.3	Write services	Partial	Requestor Services (.req/.cnf)
5.4	Combined read/write services	Partial	Requestor Services (.req/.cnf)
5.5	Network services	NO	–
5.6	Mailbox	NO	–
6.	Local interactions	–	–
6.1	Read local	YES	–
6.2	Write local	YES	–

Table 139 – CP 12/1: DLL protocol selection

Clause	Header	Presence	Constraints
4	Overview of the DL-protocol	–	–
4.1	Operating principle	YES	–
4.2	Topology	YES	–
4.3	Frame processing principles	YES	–
4.4	Data-link layer overview	YES	–
4.5	Error detection overview	YES	–
4.6	Node reference model	YES	–
4.7	Operation overview	Partial	Direct mode mandatory
5	Frame Sructure	–	–
5.1	Frame coding principles	YES	–
5.2	Data types and encoding rules	Partial	Types needed for application and unsigned integer types
5.3	DL PDU structure	YES	–
5.4	Type 12 DLPDU structure	YES	–
5.5	Network variable structure	NO	–
5.6	Type 12 mailbox structure	NO	–
6	Attributes	–	–
6.1	Management	YES	–
6.2	Statistics	YES	–
6.3	Watchdogs	YES	–
6.4	Slave information interface	YES	–
6.5	Media independent interface (MII)	YES	–
6.6	Fieldbus memory management unit (FMMU)	YES	–

Clause	Header	Presence	Constraints
6.7	Sync manager	YES	–
6.8	Distributed Clock	Partial	Timestamping of messages if more than 2 ports
7	DL-user memory	–	
7.1	Overview	YES	–
7.2	Mailbox access type	YES	–
7.3	Buffered access type	YES	–
8	Type 12:FDL Protocol state machines	–	–
8.1	Overview of slave DL state machines	NO	–
8.2	State machine description	–	–
8.2.1	Port state machine (PSM)	NO	–
8.2.2	PDU handler state machine (DHSM)	NO	–
8.2.3	Synch manager state machine (SYMSM)	NO	–
8.2.4	Resilient Mailbox State Machine (RMSM)	NO	–
8.2.5	SII State Machine (SIISM)	NO	–
8.2.6	MII State Machine (MIISM)	NO	–
8.2.7	DC State Machine (DCSM)	NO	–

13.2.3 Application layer

13.2.3.1 EtherCAT Slave

The application layer is described in IEC 61158-5-12 and IEC 61158-6-12. Table 140 specifies the use of the services, specified in IEC 61158-5-12, included in this profile. Table 141 specifies the use of the protocol, specified in IEC 61158-6-12, included in this profile.

Table 140 – CP 12/1: AL service selection

Clause	Header	Presence	Constraints
4	Concepts	–	–
4.1	Common concepts	YES	–
4.2	Type specific concepts	–	–
4.2.1	Operating principle	YES	–
4.2.2	Communication model overview	YES	–
4.2.3	Application layer element description	YES	–
4.2.4	Slave reference model	YES	–
4.2.5	Master reference model	NO	–
5	Data Type ASE	YES	–
6	Communication model specification	–	–
6.1	ASEs	–	–
6.1.1	Process data ASE	YES	–
6.1.2	SII ASE	Partial	Mandatory objects, no categories required
6.1.3	Isochronous ASE	NO	–
6.1.4	CoE ASE	NO	–
6.1.5	EoE ASE	NO	–
6.1.6	FoE ASE	NO	–
6.1.7	MBX ASE	NO	–
6.2	AR	YES	–

Table 141 – CP 12/1: AL protocol selection

Clause	Header	Presence	Constraints
4	Application Layer protocol specification	–	–
4.1	Operating principle	YES	–
4.2	Node reference model	YES	–
5	FAL syntax description	–	–
5.1	Coding principles	YES	–
5.2	Data types and encoding rules	YES	–
5.3	AR coding	YES	No Bootstrap
5.4	SII coding	YES	–
5.5	Isochronous PDI coding	NO	–
5.6	CoE coding	NO	–
5.7	EoE coding	NO	–
5.8	FoE coding	NO	–
6	FAL protocol state machine		–
6.1	Overall structure	YES	–
6.2	AP-Context state machine	YES	–
6.3	FAL service protocol machine (FSPM)	YES	–
6.4	Application Relationship Protocol Machines (ARPMs)	–	–
6.4.1	AL state machine	YES	No Bootstrap and start mailbox required
6.4.2	Mailbox handler state machine	Optional	–
6.4.3	CoE state machine	NO	–
6.4.4	EoE state machine	NO	–
6.4.5	FoE state machine	NO	–
6.5	DLL mapping protocol machine (DMPM)	YES	–

13.2.3.2 EtherCAT master

The application layer is described in IEC 61158-5-12 and IEC 61158-6-12. Table 142 specifies the use of the services, specified in IEC 61158-5-12, included in this profile. Table 143 specifies the use of the protocol, specified in IEC 61158-6-12, included in this profile.

Table 142 – CP 12/1: AL service selection

Clause	Header	Presence	Constraints
4	Concepts	–	–
4.1	Common concepts	YES	–
4.2	Type specific concepts	–	–
4.2.1	Operating principle	YES	–
4.2.2	Communication model overview	YES	–
4.2.3	Application layer element description	YES	–
4.2.4	Slave reference model	NO	–
4.2.5	Master reference model	YES	–
5	Data Type ASE	YES	–
6	Communication model specification	–	–
6.1	ASEs	–	–
6.1.1	Process data ASE	YES	–
6.1.2	SII ASE	Partial	Mandatory objects, no categories required
6.1.3	Isochronous ASE	NO	–

Clause	Header	Presence	Constraints
6.1.4	CoE ASE	NO	–
6.1.5	EoE ASE	NO	–
6.1.6	FoE ASE	NO	–
6.1.7	MBX ASE	NO	–
6.2	AR	YES	–

Table 143 – CP 12/1: AL protocol selection

Clause	Header	Presence	Constraints
4	Application Layer protocol specification	–	–
4.1	Operating principle	YES	–
4.2	Node reference Model	YES	–
5	FAL syntax description	–	–
5.1	Coding principles	YES	–
5.2	Data types and encoding rules	YES	–
5.3	AR coding	YES	No Bootstrap
5.4	SII coding	YES	–
5.5	Isochronous PDI coding	NO	–
5.6	CoE coding	NO	–
5.7	EoE coding	NO	–
5.8	FoE coding	NO	–
6	FAL protocol state machine		–
6.1	Overall structure	YES	–
6.2	AP-Context state machine	YES	–
6.3	FAL service protocol machine (FSPM)	YES	–
6.4	Application Relationship Protocol Machines (ARPMs)	–	–
6.4.1	AL state machine	NO	–
6.4.2	Mailbox handler state machine	NO	–
6.4.3	CoE state machine	NO	–
6.4.4	EoE state machine	NO	–
6.4.5	FoE state machine	NO	–
6.5	DLL mapping protocol machine (DMPM)	YES	–

13.2.4 Performance indicator selection

13.2.4.1 Performance indicator overview

Table 144 gives an overview of the performance indicator usage.

Table 144 – CP 12/1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	NO	Slave device includes switch functionality
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	NO	–
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	Optional	–

13.2.4.2 Performance indicator dependencies

Table 145 specifies the dependencies of the performance indicators (row) from the performance indicators (column).

Table 145 – CP 12/1: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non- RTE band width	Non time- based synch ron. accu racy	Redundancy re covery time
Delivery time		YES 13.2.4.4	NO	YES 13.2.4.5	NO	NO	YES 13.2.4.6
Number of end-stations	NO		NO	NO	NO	YES 13.2.4.7	NO
Basic network topology	NO	NO		NO	NO	NO	YES 13.2.4.8
Throughput RTE	NO	NO	NO		YES 13.2.4.9	NO	NO
Non-RTE bandwidth	NO	NO	NO	YES 13.2.4.9		NO	NO
Non-time-based synchronization accuracy	NO	YES 13.2.4.7	NO	NO	NO		NO
Redundancy recovery time	NO	NO	YES 13.2.4.8	NO	NO	NO	

Table 146 gives an outline of the range of performance indicators.

Table 146 – CP 12/1: PI ranges

Performance indicator	Value	Explanation
Delivery time	20 µs – 1 s	–
Number of end-stations	Up to 65 535	–
Number of switches between end-stations	Not practically limited by the protocol	EtherCAT slaves are 2-port switches
Throughput RTE	1% – 100 %	–
Non-RTE bandwidth	99 % – 0 %	–
Non-time-based synchronization accuracy	1µs – 10 µs	Depends upon topology
Redundancy recovery time	1 cycle	–

13.2.4.3 Calculation of delivery time

The performance indicator delivery time can be calculated by Formula (59).

$$t_D = t_{cycle} + t_{data} + t_{cd} \times l_{tc} + \sum_{i=1}^{NoS} t_{pd}(i) + t_{cpdl} \qquad (59)$$

where

t_D	is the delivery time;
t_{cycle}	is the cycle time ($t_{cycle} \geq t_{data}$);
t_{data}	is the time to transmit the longest Real-time Ethernet frame (80 ns/octet);
t_{cd}	is the cable delay (4,5 – 5 ns/m);
l_{tc}	is the total cable length in m;
Pd	is the propagation delay of a slave (implementation dependent);
NoS	is the number of slaves;
t_{cpdl}	is the data copy delay within a slave (typical value: $<$ 100 ns).

The cycle time is independent from the propagation delay of the connected slaves and from the cable delays, since the full-duplex capabilities of the system allow to send the next frame before the initial frame has returned to the master device. The minimum cycle time thus is only limited by the transmission time of the longest RTE frame in the given application scenario. The master implementation may further restrict this minimum cycle time.

13.2.4.4 Delivery time dependency on number of end-stations

The number of end-stations typically influences the amount of data, thus the time to transmit the data frame as well as the sum of propagation delays and hence the delivery time as described in Formula (59).

13.2.4.5 Delivery time dependency on throughput RTE

The delivery time depends on throughput RTE via data and cycle time, since throughput RTE can be adapted primarily by changing these two parameters. If throughput RTE is increased by increasing the amount of data without changing the cycle time, the delivery time is increased, too. If throughput RTE is increased by reducing the cycle time, the delivery time is reduced. If throughput RTE is increased by changing both parameters accordingly, the delivery time is not influenced as described in Formula (59).

13.2.4.6 Delivery time dependency on redundancy recovery time

Redundancy recovery time influences the cycle time and hence the delivery time as described in Formula (59).

13.2.4.7 Relation between number of end-stations and non-time-based synchronization accuracy

Number of end-stations influences the non-time-based synchronization accuracy and vice versa.

13.2.4.8 Relation between basic network topology and redundancy recovery time

Since cable redundancy determines the topology as such, the requirement for a finite redundancy recovery time influences the basic network topology and vice versa.

13.2.4.9 Relation between throughput RTE and non-RTE bandwidth

The non-RTE bandwidth is the difference between overall bandwidth and the RTE throughput (RTE overhead included) hence both values influence each other.

13.2.4.10 Consistent set of performance indicators for mid size automation system

Table 147 gives an outline of a consistent set of performance indicators for CP 12/1 for mid size automation systems with a cycle time of 60 μs.

Table 147 – CP 12/1: Consistent set of PIs for mid size automation systems

Performance indicator	Value	Constraints
Delivery time	< 150 µs	Without failure
Number of end-stations	180	–
Number of switches between end-stations	NA	–
Throughput RTE	10 750 000 octets/s	–
Non-RTE bandwidth	50,6 %	–
Non-time-based synchronization accuracy	10 µs	–
Redundancy recovery time	60 µs	–

13.3 Profile CP 12/2

13.3.1 Physical layer

The physical layer is the same as described in 13.2.1.

13.3.2 Data-link layer

13.3.2.1 EtherCAT Slave

The data-link layer is described in IEC 61158-3-12 and 61158-4-12. Table 148 specifies the use of the services, specified in IEC 61158-3-12, included in this profile. Table 149 specifies the use of the protocol, specified in IEC 61158-4-12, included in this profile.

Table 148 – CP 12/2: DLL service selection

Clause	Header	Presence	Constraints
4	Data-link layer services and concepts	–	–
4.1	Operating principle	YES	–
4.2	Topology	YES	–
4.3	Data-link layer overview	YES	–
4.4	Error detection overview	YES	–
4.5	Parameter and process data handling introduction	Partial	Some example are not describing mandatory functions
4.6	Node reference model	YES	–
4.7	Operation overview	Partial	Direct mode mandatory
4.8	Addressing	YES	–
4.9	Slave classification	Partial	Basic slave mandatory
4.10	Structure of the communication layer in the slave	YES	–
5	Communication services	–	–
5.1	Overview	YES	–
5.2	Read services	Partial	Responder Services (.ind/.rsp)
5.3	Write services	Partial	Responder Services (.ind/.rsp)
5.4	Combined read/write services	Partial	Responder Services (.ind/.rsp)
5.5	Network services	NO	–
5.6	Mailbox	NO	–
6.	Local interactions	–	–
6.1	Read local	YES	–
6.2	Write local	YES	–

Table 149 – CP 12/2: DLL protocol selection

Clause	Header	Presence	Constraints
4	Overview of the DL-protocol	–	–
4.1	Operating principle	YES	–
4.2	Topology	YES	–
4.3	Frame processing principles	YES	–
4.4	Data-link layer overview	YES	–
4.5	Error detection overview	YES	–
4.6	Node reference model	YES	–
4.7	Operation overview	Partial	Direct mode mandatory
5	Frame Sructure	–	–
5.1	Frame coding principles	YES	–
5.2	Data types and encoding rules	Partial	Types needed for application and unsigned integer types
5.3	DL PDU structure	YES	–
5.4	Type 12 DLPDU structure	YES	–
5.5	Network variable structure	NO	–
5.6	Type 12 mailbox structure	NO	–
6	Attributes	–	–
6.1	Management	YES	–
6.2	Statistics	YES	–
6.3	Watchdogs	YES	–
6.4	Slave information interface	YES	–
6.5	Media independent interface (MII)	YES	–
6.6	Fieldbus memory management unit (FMMU)	YES	–
6.7	Sync manager	YES	–
6.8	Distributed Clock	Optional	If time based synchronization is supported
7	DL-user memory	–	
7.1	Overview	YES	–
7.2	Mailbox access type	YES	–
7.3	Buffered access type	YES	–
8	Type 12:FDL Protocol state machines	–	–
8.1	Overview of slave DL state machines	YES	–
8.2	State machine description	–	–
8.2.1	Port state machine (PSM)	YES	–
8.2.2	PDU handler state machine (DHSM)	YES	–
8.2.3	Synch manager state machine (SYMSM)	YES	–
8.2.4	Resilient Mailbox State Machine (RMSM)	YES	–
8.2.5	SII State Machine (SIISM)	YES	–
8.2.6	MII State Machine (MIISM)	YES	–
8.2.7	DC State Machine (DCSM)	YES	–

13.3.2.2 EtherCAT Master

The data-link layer is described in IEC 61158-3-12 and IEC 61158-4-12. Table 150 specifies the use of the services, specified in IEC 61158-3-12, included in this profile. Table 151 specifies the use of the protocol, specified in IEC 61158-3-12, included in this profile. The selection of services used is up to the master. The Auto Increment Read and Write Services are mandatory.

Table 150 – CP 12/2: DLL service selection

Clause	Header	Presence	Constraints
4	Data-link layer services and concepts	–	–
4.1	Operating principle	YES	–
4.2	Topology	YES	–
4.3	Data-link layer overview	YES	–
4.4	Error detection overview	YES	–
4.5	Parameter and process data handling introduction	YES	–
4.6	Node reference model	YES	–
4.7	Operation overview	Partial	Direct mode mandatory
4.8	Addressing	YES	–
4.9	Slave classification	NO	–
4.10	Structure of the communication layer in the slave	YES	–
5	Communication services	–	–
5.1	Overview	YES	–
5.2	Read services	Partial	Requestor Services (.req/.cnf)
5.3	Write services	Partial	Requestor Services (.req/.cnf)
5.4	Combined read/write services	Partial	Requestor Services (.req/.cnf)
5.5	Network services	NO	–
5.6	Mailbox	NO	–
6	Local interactions	–	–
6.1	Read local	YES	–
6.2	Write local	YES	–

Table 151 – CP 12/2: DLL protocol selection

Clause	Header	Presence	Constraints
4	Overview of the DL-protocol	–	–
4.1	Operating principle	YES	–
4.2	Topology	YES	–
4.3	Frame processing principles	YES	–
4.4	Data-link layer overview	YES	–
4.5	Error detection overview	YES	–
4.6	Node reference model	YES	–
4.7	Operation overview	Partial	Direct mode mandatory
5	Frame Sructure	–	–
5.1	Frame coding principles	YES	–
5.2	Data types and encoding rules	Partial	Types needed for application and unsigned integer types
5.3	DL PDU structure	YES	–
5.4	Type 12 DLPDU structure	YES	–
5.5	Network variable structure	NO	–
5.6	Type 12 mailbox structure	NO	–
6.	Attributes	–	–
6.1	Management	YES	–
6.2	Statistics	YES	–
6.3	Watchdogs	YES	–
6.4	Slave information interface	YES	–
6.5	Media independent interface (MII)	YES	–
6.6	Fieldbus memory management unit (FMMU)	YES	–

Clause	Header	Presence	Constraints
6.7	Sync manager	YES	–
6.8	Distributed Clock	Optional	If time based synchronization is supported
7	DL-user memory	–	
7.1	Overview	YES	–
7.2	Mailbox access type	YES	–
7.3	Buffered access type	YES	–
8	Type 12:FDL Protocol state machines	–	–
8.1	Overview of slave DL state machines	NO	–
8.2	State machine description	–	–
8.2.1	Port state machine (PSM)	NO	–
8.2.2	PDU handler state machine (DHSM)	NO	–
8.2.3	Synch manager state machine (SYMSM)	NO	–
8.2.4	Resilient Mailbox State Machine (RMSM)	NO	–
8.2.5	SII State Machine (SIISM)	NO	–
8.2.6	MII State Machine (MIISM)	NO	–
8.2.7	DC State Machine (DCSM)	NO	–

13.3.3 Application layer

13.3.3.1 EtherCAT Slave

The application layer is described in IEC 61158-5-12 and IEC 61158-6-12. Table 152 specifies the use of the services, specified in IEC 61158-5-12, included in this profile. Table 153 specifies the use of the protocol, specified in IEC 61158-6-12, included in this profile.

Table 152 – CP 12/2: AL service selection

Clause	Header	Presence	Constraints
4	Concepts	–	–
4.1	Common concepts	YES	–
4.2	Type specific concepts	–	–
4.2.1	Operating principle	YES	–
4.2.2	Communication model overview	YES	–
4.2.3	Application layer element description	YES	–
4.2.4	Slave reference model	YES	–
4.2.5	Master reference model	NO	–
5	Data Type ASE	YES	–
6	Communication model specification	–	–
6.1	ASEs	–	–
6.1.1	Process data ASE	YES	–
6.1.2	SII ASE	YES	–
6.1.3	Isochronous ASE	Optional	–
6.1.4	CoE ASE	Optional	–
6.1.5	EoE ASE	Optional	–
6.1.6	FoE ASE	Optional	–
6.1.7	MBX ASE	Optional	–
6.2	AR	YES	–

Table 153 – CP 12/2: AL protocol selection

Clause	Header	Presence	Constraints
4	Application Layer protocol specification	–	–
4.1	Operating principle	YES	–
4.2	Node reference model	YES	–
5	FAL syntax description	–	–
5.1	Coding principles	YES	–
5.2	Data types and encoding rules	YES	–
5.3	AR coding	YES	Bootstrap optional
5.4	SII coding	YES	–
5.5	Isochronous PDI coding	Optional	–
5.6	CoE coding	Optional	–
5.7	EoE coding	Optional	–
5.8	FoE coding	Optional	–
6	FAL protocol state machine		–
6.1	Overall structure	YES	–
6.2	AP-Context state machine	YES	–
6.3	FAL service protocol machine (FSPM)	YES	–
6.4	Application Relationship Protocol Machines (ARPMs)	–	–
6.4.1	AL state machine	YES	Bootstrap optional
6.4.2	Mailbox handler state machine	YES	–
6.4.3	CoE state machine	Optional	–
6.4.4	EoE state machine	Optional	–
6.4.5	FoE state machine	Optional	–
6.5	DLL mapping protocol machine (DMPM)	YES	–

13.3.3.2 EtherCAT Master

The application layer is described in IEC 61158-5-12 and IEC 61158-6-12. Table 154 specifies the use of the services, specified in IEC 61158-5-12, included in this profile. Table 155 specifies the use of the protocol, specified in IEC 61158-6-12, included in this profile.

Table 154 – CP 12/2: AL service selection

Clause	Header	Presence	Constraints
4	Concepts	–	–
4.1	Common concepts	YES	–
4.2	Type specific concepts	–	–
4.2.1	Operating principle	YES	–
4.2.2	Communication model overview	YES	–
4.2.3	Application layer element description	YES	–
4.2.4	Slave reference model	NO	–
4.2.5	Master reference model	YES	–
5	Data Type ASE	YES	–
6	Communication model specification	–	–
6.1	ASEs	–	–
6.1.1	Process Data ASE	YES	–
6.1.2	SII ASE	YES	–
6.1.3	Isochronous ASE	Optional	–
6.1.4	CoE ASE	YES	–

Clause	Header	Presence	Constraints
6.1.5	EoE ASE	Optional	–
6.1.6	FoE ASE	Optional	–
6.1.7	MBX ASE	Optional	–
6.2	AR	YES	–

Table 155 – CP 12/2: AL protocol selection

Clause	Header	Presence	Constraints
4	Application Layer protocol specification	–	–
4.1	Operating principle	YES	–
4.2	Node reference Model	YES	–
5	FAL syntax description	–	–
5.1	Coding principles	YES	–
5.2	Data types and encoding rules	YES	–
5.3	AR coding	YES	Bootstrap optional
5.4	SII coding	YES	–
5.5	Isochronous PDI coding	Optional	–
5.6	CoE coding	YES	–
5.7	EoE coding	Optional	–
5.8	FoE coding	Optional	–
6	FAL protocol state machine		–
6.1	Overall structure	YES	–
6.2	AP-Context state machine	YES	–
6.3	FAL service protocol machine (FSPM)	YES	–
6.4	Application Relationship Protocol Machines (ARPMs)	–	–
6.4.1	AL state machine	NO	–
6.4.2	Mailbox handler state machine	NO	–
6.4.3	CoE state machine	YES	–
6.4.4	EoE state machine	Optional	–
6.4.5	FoE state machine	Optional	–
6.5	DLL mapping protocol machine (DMPM)	YES	–

13.3.4 Performance indicator selection

13.3.4.1 Performance indicator overview

The performance indicator overview of 13.2.4.1 applies.

Table 156 gives an overview of the performance indicator usage.

Table 156 – CP 12/2: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	NO	Slave Device includes switch functionality
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	–
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	Optional	–

13.3.4.2 Performance indicator dependencies

Table 157 specifies the dependencies of the performance indicators (row) from the performance indicators (column).

Table 157 – CP 12/2: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchron. accuracy	Non time- based synchron. accuracy	Redundancy recovery time
Delivery time		YES 13.2.4.4	NO	YES 13.2.4.5	NO	NO	NO	YES 13.2.4.6
Number of end-stations	NO		NO	NO	NO	YES 13.3.4.4	YES 13.2.4.7	NO
Basic network topology	NO	NO		NO	NO	NO	NO	YES 13.2.4.8
Throughput RTE	NO	NO	NO		YES 13.2.4.9	NO	NO	NO
Non-RTE bandwidth	NO	NO	NO	YES 13.2.4.9		NO	NO	NO
Time synchronization accuracy	NO	YES 13.3.4.4	NO	NO	NO		NO	NO
Non-time-based synchronization accuracy	NO	YES 13.2.4.7	NO	NO	NO	NO		NO
Redundancy recovery time	NO	NO	YES 13.2.4.8	NO	NO	NO	NO	

13.3.4.3 Calculation of delivery time

The delivery time is calculated according to Formula (59).

13.3.4.4 Relation between number of end-stations and time synchronization accuracy

Number of end-stations influences the time synchronization accuracy and vice versa.

13.3.4.5 Consistent set of performance indicators for large automation systems

Table 158 gives an outline of a consistent set of performance indicators for a large automation system with a cycle time of 200 μs and 500 m network extension.

Table 158 – CP 12/2: Consistent set of PIs

Performance indicator	Value	Constraints
Delivery time	< 519 μs	No failure
Number of end-stations	650	–
Number of switches between end-stations	NA	–
Throughput RTE	10 500 000 octets/s	–
Non-RTE bandwidth	55,9 %	–
Time synchronization accuracy	<< 1 μs	Depends on slave device hardware implementation, typically less than 200 ns
Non-time-based synchronization accuracy	10 μs	–
Redundancy recovery time	200 μs	–

14 Communication Profile Family 13 (Ethernet POWERLINK[11]) – RTE communication profiles

14.1 General overview

Communication Profile Family 13 (CPF 13) defines a profile using Type 13 of the IEC 61158 series, which correspond to the communication system commonly known as Ethernet POWERLINK.

– Profile 13/1

  This profile contains AL, and DLL services and protocol definitions from IEC 61158-3-13, IEC 61158-4-13, IEC 61158-5-13 and IEC 61158-6-13.

Table 159 shows the overview of Ethernet POWERLINK profile set.

Table 159 – CPF 13: Overview of profile sets

Layer	Profile 13/1
Application	IEC 61158-5-13, IEC 61158-6-13
Data-link	IEC 61158-3-13, IEC 61158-4-13
Physical	ISO/IEC 8802-3

14.2 Profile 13/1

14.2.1 Physical layer

The physical layer shall be according to ISO/IEC 8802-3.

[11] Ethernet POWERLINK is a trade name of Bernecker&Rainer Industrieelektronik Ges.m.b.H., control of trade name use is given to the non profit organization EPSG. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

14.2.2 Data-link layer

14.2.2.1 DLL services selection

The data-link layer services are defined in IEC 61158-3-13. Table 160 shows the subclauses included in this profile.

Table 160 – CP 13/1: DLL service selection

Clause	Header	Presence	Constraints
Whole document	Data link service specification (Type 13)	YES	–

14.2.2.2 DLL protocol selection

The data-link layer protocols are defined in IEC 61158-4-13. Table 161 shows the subclauses included in this profile.

Table 161 – CP 13/1: DLL protocol selection

Clause	Header	Presence	Constraints
Whole document	Data link protocol specification (Type 13)	YES	–

14.2.3 Application layer

14.2.3.1 AL service selection

The application layer services are defined in IEC 61158-5-13. Table 162 shows the subclauses included in this profile.

Table 162 – CP 13/1: AL service selection

Clause	Header	Presence	Constraints
Whole document	Application layer service specification (Type 13)	YES	–

14.2.3.2 AL protocol selection

The application layer protocols are defined in IEC 61158-6-13. Table 163 shows the subclauses included in this profile.

Table 163 – CP 13/1: AL protocol selection

Clause	Header	Presence	Constraints
Whole document	Application layer protocol specification (Type 13)	YES	–

14.2.4 Performance indicator selection

14.2.4.1 Performance indicator overview

Table 164 shows the performance indicators overview of CP 13/1.

Table 164 – CP 13/1: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	Star and linear topology
Number of switches between end-stations	YES	For highest performance use repeaters instead of switches
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	–
Non time-based synchronization accuracy	YES	–
Redundancy recovery time	YES	–

14.2.4.2 Performance indicator dependencies

14.2.4.2.1 Performance indicator dependency matrix

Table 165 shows the dependencies between performance indicators for CP 13/1.

Table 165 – CP 13/1: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchron. accuracy	Non time- based synchron. accuracy	Redundancy recovery time
Delivery time		YES 14.2.4.2.5	YES 14.2.4.2.6	YES 14.2.4.2.8	NO	NO	NO	NO
Number of end-stations	YES 14.2.4.2.3		NO	NO	NO	NO	NO	NO
Basic network topology	YES 14.2.4.2.4	NO		NO	NO	YES 14.2.4.2.11	YES 14.2.4.2.12	YES 14.2.4.2.13
Throughput RTE	NO	NO	NO		YES 14.2.4.2.10	NO	NO	NO
Non-RTE bandwidth	NO	NO	YES 14.2.4.2.7	YES 14.2.4.2.9		NO	NO	NO
Time synchronization accuracy	NO	NO	NO	NO	NO		NO	NO
Non-time-based synchronization accuracy	NO	NO	NO	NO	NO	NO		NO
Redundancy recovery time	NO	NO	NO	NO	NO	NO	NO	

14.2.4.2.2 Delivery time

The delivery time is dependent on the communication cycle time and properties of the specific end-station. Data which is produced is transmitted in the following communication cycle and processed by the receiving node at the beginning of the third communication cycle.

The delivery time for communication between two RTE end-stations can be calculated by Formula (60).

$$T_D = T_{PS} + T_C + T_{PR} \tag{60}$$

where

T_D	is the delivery time;
T_C	is the communication cycle time, see Formula (61);
T_{PR}	is the processing time in the receiving end-station.
T_{PS}	is the processing time in the sending end-station.

The communication cycle time T_C can be calculated by Formula (61).

$$T_C = T_S + T_A + \sum_{i=1}^{N} \left(T_{FT,i} + T_{RD,i} + T_{SD,i} \right) \tag{61}$$

where

T_C	is the communication cycle time;
T_S	is the communication cycle start delay;
N	is the number of RTE end-stations processed in one communication cycle;
$T_{FT,i}$	is the RTE frames transmission time for RTE end-station i (depends on the amount of APDU data for this node);
$T_{RD,i}$	is the response delay of the RTE end-station i;
$T_{SD,i}$	is the sum of all delays of infrastructure components (switches, repeaters, cabling) for the RTE end-station i;
T_A	is the time reserved for non-RTE data within one communication cycle.

The delivery time with one lost frame for communication between two RTE end-stations can be calculated by Formula (62).

$$T_D = T_{PS} + 2 \times T_C + T_{PR} \tag{62}$$

where

T_D	is the delivery time;
T_C	is the communication cycle time, see Formula (61);
T_{PR}	is the processing time in the receiving end-station.
T_{PS}	is the processing time in the sending end-station.

14.2.4.2.3 Delivery time dependency on number of end-stations

Typically the amount of APDU data increases with the number of end-stations. Moreover additional delays are introduced with every extra node (by the node itself and additional network infrastructure components if necessary). Both parameters are considered in Formula (61) and therefore influence the delivery time as calculated by Formula (60).

14.2.4.2.4 Delivery time dependency on basic network topology

Basic network topology influences signal propagation delay between two RTE end-stations which limits the communication cycle time and consequently the delivery time.

14.2.4.2.5 Number of end-stations dependency on delivery time

As shown in Formula (60) the delivery time is given by the communication cycle time. As every node occupies a certain amount of time within the communication cycle there is a limit on the number of nodes if a certain delivery time is to be accomplished.

14.2.4.2.6 Basic network topology dependency on delivery time

A given delivery time limits the amount of tolerable signal propagation delays which are introduced by a given network topology.

14.2.4.2.7 Basic network topology dependency on non-RTE bandwidth

Non-RTE bandwidth is provided by a fixed time slice of the communication cycle and therefore dependent on delivery time. From this it follows that basic network topology is also dependent on non-RTE bandwidth.

14.2.4.2.8 Throughput RTE dependency on delivery time

A certain delivery time limits the amount of APDU which can be transmitted within one communication cycle. Throughput RTE is a function of APDU size and communication cycle time and therefore dependent on delivery time.

14.2.4.2.9 Throughput RTE dependency on non-RTE bandwidth

Non-RTE bandwidth is provided by a fixed time slice of one communication cycle. This time slice can not be used for real-time data and therefore limits throughput RTE.

14.2.4.2.10 Non-RTE bandwidth dependency on Throughput RTE

Non-RTE bandwidth is provided by a fixed time slice of one communication cycle. More RTE data sent within one communication cycle reduces the time available for non-RTE communication.

Non-RTE bandwidth is derived from the communication cycle time and network maximum transmission unit (MTU) size as calculated by Formula (63). Total link bandwidth corresponds to full link rate according ISO/IEC 8802-3 (e.g. 100 Mbit/s).

$$B_{NRTE} = \frac{M}{125\,000 \times T_C} \qquad (63)$$

where

B_{NRTE}	is the non-RTE bandwidth;
M	is the network MTU in octets;
T_C	is the communication cycle time.

14.2.4.2.11 Time synchronization accuracy dependency on basic network topology

On the transmission path between two communicating RTE end-stations several switches (or other network infrastructure components) can be traversed, each causing jitter of the receive time, thus influencing the time synchronization accuracy.

14.2.4.2.12 Non-time-based synchronization accuracy dependency on basic network topology

Subclause 14.2.4.2.8 applies.

14.2.4.2.13 Redundancy recovery time dependency on basic network topology

Basic network topology determines duration and method of failure detection and recovery.

14.2.4.3 Consistent set of performance indicators

Table 166 shows one consistent set of performance indicators for CP 13/1 using a network bandwidth of 100 Mbit/s. The values in Table 166 represent a practical example of a small sized system for machine automation. This system operates at a communication cycle time of 150 µs and is connected by a realistic network infrastructure using star topology. The numerical calculations are based on worst case performance values of devices widely installed in the field for this type of automation system.

Table 166 – CP 13/1: Consistent set of PIs small size automation system

Performance indicator	Value	Constraints
Delivery Time	350 µs	Processing time is 100 µs at sender and receiver, no failure
Number of end-stations	4	
Number of switches between end-stations	0	1 Repeater used instead of switches
Throughput RTE	1,9 Moctets/s	
Non-RTE bandwidth	19,6 %	Network MTU is 369 octets
Time synchronization accuracy	$<$ 1 s	Implementation dependent
Non time-based synchronization accuracy	$<$ 200 ns	Depends on location of node within network topology
Redundancy recovery time	150 µs	

Table 167 shows one consistent set of performance indicators for CP 13/1 using a network bandwidth of 100 Mbit/s. The values in Table 167 represent a practical example of a medium sized system for machine automation. This system operates at a communication cycle time of 500 µs and is connected by a realistic network infrastructure using combined star and linear topology. The numerical calculations are based on worst case performance values of devices widely installed in the field for this type of automation system.

Table 167 – CP 13/1: Consistent set of PIs medium size automation system

Performance indicator	Value	Constraints
Delivery Time	700 µs	Processing time is 100 µs at sender and receiver, no failure
Number of end-stations	20	
Number of switches between end-stations	0	7 Repeaters used instead of switches
Throughput RTE	2,5 Moctets/s	
Non-RTE bandwidth	11,5 %	Network MTU is 720 octets
Time synchronization accuracy	$<$ 1 s	Implementation dependent
Non time-based synchronization accuracy	$<$ 440 ns	Depends on location of node within network topology
Redundancy recovery time	500 µs	

Table 168 shows one consistent set of performance indicators for CP 13/1 using a network bandwidth of 100 Mbit/s. The values in Table 168 represent a practical example of a large sized system for machine or process automation. This system operates at a communication cycle time of 2 700 μs and is connected by network infrastructure using star topology. The numerical calculations are based on worst case performance values of devices widely installed in the field for this type of automation system.

Table 168 – CP 13/1: Consistent set of PIs large size automation system

Performance indicator	Value	Constraints
Delivery Time	2 900 μs	Processing time is 100 μs at sender and receiver, no failure
Number of end-stations	150	
Number of switches between end-stations	0	3 Repeaters used instead of switches
Throughput RTE	4 Moctets/s	
Non-RTE bandwidth	4,4 %	Network MTU is 1 500 octets
Time synchronization accuracy	< 1 s	Implementation dependent
Non time-based synchronization accuracy	< 280 ns	Depends on location of node within network topology
Redundancy recovery time	2 700 μs	

15 Communication Profile Family 14 (EPA[12])- RTE communication profiles

15.1 General overview

Communication Profile Family 14 (CPF 14) defines communication profiles based on IEC 61158-3-14, IEC 61158-4-14, IEC 61158-5-14 and IEC 61158-6-14, which correspond to parts of the communication systems commonly known as real-time EPA (Ethernet for Plant Automation).

– Profile 14/1

  This profile contains a selection of AL, DLL and PHL services and protocol definitions from IEC 61158-3-14, IEC 61158-4-14, IEC 61158-5-14 and IEC 61158-6-14. This profile provides real time communication using IEEE 802 series and IETF communication protocols with accurate time synchronization based on IEC 61588.

  This profile support communications between master devices and bridges.

– Profile 14/2

  This profile provides ISO/IEC 8802-3-based real time communication with deterministic communications defined in IEC 61158-3-14 and IEC 61158-4-14.

  This profile supports communication between field devices and bridges.

– Profile 14/3

  This profile contains a selection of AL, DLL and PHL services and protocol definitions from IEC 61158-3-14, IEC 61158-4-14, IEC 61158-5-14 and IEC 61158-6-14. This profile provides real time communication using IEEE 802 series. IETF communication protocols can be used if necessary. Accurate time synchronization based on IEC 61588 should be used.

– Profile 14/4

[12] EPA™ is a trade name of SUPCON Group Co. Ltd. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

This profile provides ISO/IEC 8802-3-based real time communication with deterministic communications defined in IEC 61158-3-14 and IEC 61158-4-14. This profile contains a selection of AL services and protocol definitions from IEC 61158-5-14 and IEC 61158-6-14.

This profile supports communication between master devices and field devices.

15.2 CPF 14 (EPA) communication concept

15.2.1 General

The EPA system is a distributed system which uses the Ethernet network defined by ISO/IEC 8802-3, IEEE 802 series and IETF protocols to connect field devices and small systems, and to control/monitor equipment in the industrial field. EPA devices work together to provide I/O and control for automated processes and operations.

The EPA system architecture provides a framework for describing these systems as the collection of physical devices interconnected by an EPA network. The objective of 15.2 is to identify the components of the system, describe their relationships and interactions, and define how they are configured.

15.2.2 Network Topology

Figure 12 shows an example of the EPA network topology with two subnets, process monitor layer subnet (L2-subnet) and field device layer subnet (L1-subnet).

The following describes the characteristics of EPA topology:

- a L1-subnet is used to connect field devices (such as transmitters, actuators and analytical instruments, etc.) mounted in field environment;
- a L1-subnet can be separated into more than one micro-segments, where the time-sharing controlling mechanism is used to meet the demands of deterministic communication;
- a L2-subnet is used to connect the devices of control center and HMI devices and one or more micro-segments. In L2-subnet, regular communication schedule based on CSMA/CD defined in ISO/IEC 8802-3 is applied when deterministic communication is not necessary;
- devices on both L1-subnets and L2-subnets may be interconnected with standard switches or hubs;
- an EPA device may function as a bridge, which interconnects a L1-subnet micro-segment to a L2-subnet. This EPA bridge performs message filtering and forwarding between L1-subnet and L2-subnet.

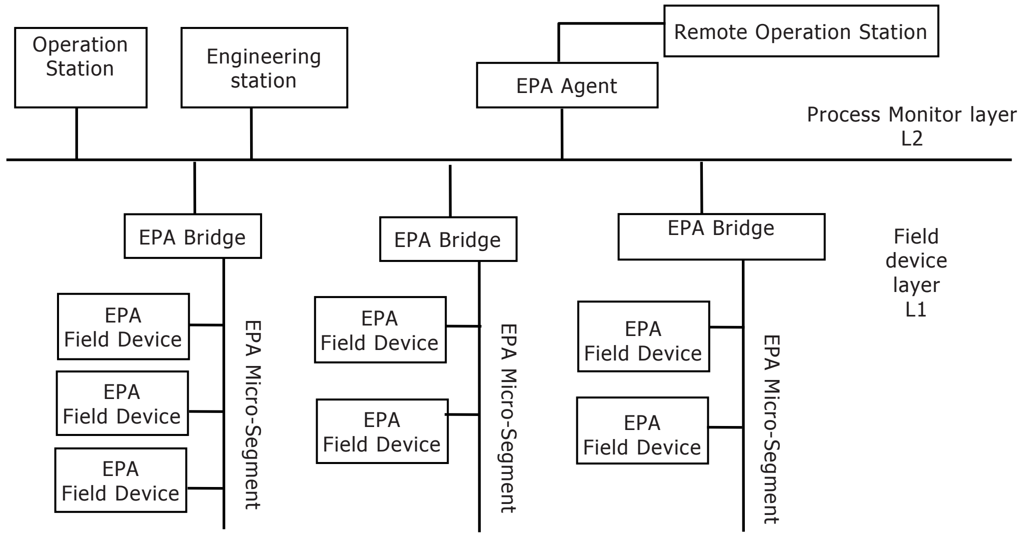

Figure 12 – EPA system network topology example

A micro-segment is a control area, where EPA devices communicate with each other to implement specific measuring and control functions. That is, the devices which need to communicate with each other shall be interconnected in the same L1 micro-segment.

Those devices consisting of a control loop or function block application process, such as transmitters, actuators and controllers which need to communicate with each other, shall be interconnected in the same micro-segment.

15.2.3 EPA devices

15.2.3.1 EPA master device

An EPA master device is connected to a L2-subnet directly. An EPA master device has an EPA communication interface but may have no control function block or function block application. An EPA master device may commonly be a configuration device, a monitoring device or a HMI station.

An EPA master device has a unique IP address in a system.

15.2.3.2 EPA field device

An EPA field device is installed in the industrial field environment. EPA field devices must have EPA a communication entity and at least include one function block instance.

An EPA field Device has a unique IP address in a system.

15.2.3.3 EPA bridge

An EPA bridge is an optional device that interconnects one L1-subnet micro-segment to a L2-subnet. An EPA bridge has at least has two communication interfaces, connecting one L1-subnet micro-segment and one L2-subnet respectively.

An EPA bridge can be configured to provide the following functions:

- communication isolation;

When the traffic occurs between two devices connected in one micro-segment, the EPA bridge shall provide limit it within the segment. Here, the traffic includes broadcast, multicast and peer to peer communication flows.

- message forwarding and filtering

  An EPA bridge transmit shall forward and filter the messages between one L1-subnet micro-segment and another L1-segment or L2-subnet. That is, when forwarding a message, the EPA bridge shall examine whether it should be forwarded according to configured criteria.

NOTE As an optional device, an EPA bridge is not necessary if the number of nodes in a system is not too large.

15.2.3.4 EPA agent

An EPA agent is an optional device used to interconnect an EPA network and other different networsk. It shall provide the function of security control for the remote access.

15.3 Profile 14/1

15.3.1 Physical layer

The physical layer of the EPA profile is according to ISO/IEC 8802-3. for wired connection, ISO/IEC 8802-11 and IEEE 802.15.1 for wireless connection

15.3.2 Data-link layer

The data-link layer shall be according to ISO/IEC 8802-3, IEEE 802-1D, ISO/IEC 8802-11 and IEEE 802.15.1.

15.3.3 Network Layer

Internet standard RFC 791 (IP), RFC 826 (ARP), RFC 792 (ICMP) and their amendments and successors shall be used.

15.3.4 Transport Layer

Internet standard RFC 768 (UDP), RFC 793 (TCP) and their amendments and successors may be used. But for real-time applications, RFC 768 shall be used for field devices, bridges and master devices.

15.3.5 Application layer

15.3.5.1 AL service selection

The application layer services for profile 14/1 are defined in IEC 61158-5-14. Table 169 specifies the clauses included in this profile.

Table 169 – CP 14/1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations	Partial	Used when applicable
4	Concepts	Partial	Used when applicable
5	Data type ASE	YES	–
6	Communication model specification	YES	–

15.3.5.2 AL protocol selection

The application layer protocols for profile 14/1 are defined IEC 61158-6-14. Table 170 specifies the clauses included in this profile.

Table 170 – CP 14/1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations	Partial	Used when applicable
4	Abstract syntax	YES	–
4.1	Fixed format PDU description	YES	–
4.2	Object definitions in FAL management ASE	YES	–
4.3	Definition of objects used in Type 14 application access entity	YES	–
5	Transfer syntax	YES	–
5.1	Encoding of basic data types	YES	–
5.2	Encoding of Type 14 APDU header	YES	–
5.3	Encoding of FAL management entity service parameters	YES	–
5.4	Encoding of AAE Services	YES	–
6	Structure of FAL protocol state machines	YES	–
7	AP-Context state machine	YES	–
8	FAL management state machines	YES	–
9	Application access entity protocol machine	YES	–
10	Application relationship state machine	YES	–
11	DLL mapping protocol machine	YES	–

15.3.6 Performance indicator selection

15.3.6.1 Performance indicator overview

Table 171 provides an overview of CP 14/1 performance indicators.

Table 171 – CP 14/1: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	YES	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	–
Non-time-based synchronization accuracy	NO	–
Redundancy recovery time	YES	–

15.3.6.2 Performance indicator dependencies

Table 172 specifies PI dependencies included in this profile.

Table 172 – CP 14/1: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchron. accurancy	Redundancy recovery time
Delivery time		YES	NO	YES	YES	NO	NO	NO
Number of end-stations	YES		NO	NO	NO	NO	NO	NO
Basic network topology	YES	NO		NO	NO	NO	YES	YES
Number of switches between end-stations	YES	NO	NO		NO	NO	YES	YES
Throughput RTE	NO	NO	NO	NO		YES	NO	NO
Non-RTE bandwidth	NO	NO	NO	NO	NO		YES	NO
Time synchronization accuracy	NO	YES	NO	YES	NO	NO		NO
Redundancy recovery time	YES	NO	YES	YES	NO	NO	NO	

15.3.6.2.1 Delivery Time

The performance indicator delivery time can be calculated by Formula (64).

$$DT = TStack\_S + TQueue\_S + TEthernet\_S + TTrf\_S \times Ndata + TCable \times LCable + TSwitch \times NSwitch + TStack\_R \quad (64)$$

where

DT	is the delivery time;
TStack_S	is the sender stack processing time;
TQueue_S	is the sender queuing delay;
TEthernet_S	is the sender traversal time through MAC and Phy based on ISO/IEC 8802-3;
TTrf_S	is the transfer time for an octet;
Ndata	is the length in octets of complete Ethernet frame;
TCable	is the cable delay;
LCable	is the cable length;
TSwitch	is the Switch delay;
NSwitch	is the Number of switches between end-stations;
TStack_R	is the receiver stack processing time including Phy and MAC.

As shown in Formula (64):

- the number of end-stations influence DT with queue delay;
- the number of switches between end-stations influences DT. DT will be longer when the number of switches between end-stations increases;
- the throughput RTE influences DT. That is, DT will be longer due to queue delay when Throughput RTE increases.

15.3.6.2.2 Number of end-stations

If the delivery time is set to the bounded delivery time, then the maximum number of end-stations is restricted.

15.3.6.2.3 Basic network topology

The basic network topology is designed in linear, star, ring or daisy-chain according to the delivery time in application. If the delivery time is preset to the boundary delivery time, the basic network topology shall be set to a hierarchical star.

If the time synchronization accuracy is set to the minimum value, the basic network topology shall be set to a hierarchical star.

If redundancy recovery time is allowed to use rapid spanning tree algorithm according to IEEE 802.1D, then the basic network topology can be designed in linear, star, ring or daisy-chain.

15.3.6.2.4 Number of switches between end-stations

The number of switches between end-stations shall be designed to a minimum value so that delivery time, time synchronization accuracy and redundancy recovery accuracy meet the application demands.

15.3.6.2.5 Relation between Throughput RTE and Non-RTE bandwidth

The relation between Throughput RTE and Non-RTE bandwidth is specified in Formula (65).

$$NRTE\_BW = ((RateofEthernet - ThroughputRTE \times 8) / RateofEthernet) \times 100\ \% \qquad (65)$$

where

NRTE_BW	is the non-RTE bandwidth, in %;
RateofEthernet	is the Ethernet data rate in Mbit/s;
ThroughputRTE	is the RTE throughput in octets/s.

Throughput RTE can be calculated by Formula (66).

$$ThroughputRTE = (\sum (RTEData + TSData + RMData)) / s \qquad (66)$$

where

ThroughputRTE	is the RTE throughput in octets/s;
RTEData	is the real-time data in octets;
TSData	is the time synchronization data in octets;
RMData	is the redundancy management data in octets.

15.3.6.2.6 Time synchronization accuracy

Time synchronization accuracy depends on synchronization cycle and switch delay. The synchronization cycle depends on the number of end-stations and the switch delay depends on the number of switches between end-stations.

15.3.6.2.7 Redundancy recovery time

The time to detect the failure is dependant from the number of switches between end-stations.

15.3.6.3 Consistent set of performance indicators

Table 173 specifies consistent set of PI included in this profile.

Table 173 – CP 14/1: Consistent set of PIs

performance indicator	value	constraints
Delivery time	5 ms 10 ms	Without failure 1 frame lost
Number of end-stations	32	Star topology with switches
Number of switches between end-stations	4	
Throughput RTE	1 536 000 octets/s	
Non-RTE bandwidth	85 %	100 Mbit/s Ethernet
Time synchronization accuracy	< 10 µs	
Redundancy recovery time	< 300 ms	

15.4 Profile 14/2

15.4.1 Physical layer

The physical layer of the EPA profile is according to ISO/IEC 8802-3. EPA devices may use a data rate of 10 Mbit/s, 100 Mbit/s and higher. The topology shall be linear, star, ring or the combination of the above.

15.4.2 Data-link layer

The data-link layer shall be according to ISO/IEC 8802-3, IEEE 802-1D.

In addition, EPA Communication Scheduling Management Entity (ECSME) is defined on ISO/IEC 8802-3 data-link services are defined in IEC 61158-3-14, and data-link protocol to manage the deterministic communication in IEC 61158-4-14.

Table 174 defines the DLL service selection from IEC 61158-3-14 for profile 14/2.

Table 174 – CP 14/2: DLL service selection

Clause	Header	Presence	constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	DL Service and concept	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DLL	YES	–
5	DL-management services	YES	–
5.1	Overview	Partial	Used when applicable
5.2	Non-periodic data annunciation	YES	–
5.3	EndofNonPeriodicDataSendingAnnunciation service	YES	–
5.4	DL-management for FRT applications	–	–

Table 175 defines the DLL protocol selections from IEC 61158-4-14 for CP14/2.

Table 175 – CP 14/2: DLL protocol selection

Clause	Header	Presence	constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations	Partial	Used when applicable
4	Overview of DL-protocol	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DL	YES	–
4.3	Structure of deterministic communication scheduling	YES	–
5	Procedure of deterministic communication scheduling	–	–
5.1	Overview	YES	–
5.2	State transitions	YES	–
5.3	State table	YES	–
5.4	Function descriptions	–	–
6	The structure and encoding of ECSME PDU	YES	–

15.4.3 Network Layer

Internet standard RFC 791 (IP), RFC 826 (ARP), RFC 792 (ICMP) and their amendments and successors shall be used.

15.4.4 Transport Layer

Internet standard RFC 768 (UDP), RFC 793 (TCP) and their amendments and successors may be used. But for real-time applications, RFC 768 shall be used for field devices, bridges and master devices.

15.4.5 Application layer

15.4.5.1 AL service selection

The application layer services for profile 14/2 are defined in IEC 61158-5-14. Table 176 specifies the clauses included in this profile.

Table 176 – CP 14/2: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Concepts	Partial	Used when applicable
5	Data type ASE	YES	–
6	Communication model specification	YES	–

15.4.5.2 AL protocol selection

The application layer protocol for profile 14/2 is defined in IEC 61158-6-14. Table 177 specifies the clauses included in this profile.

Table 177 – CP 14/2: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Abstract syntax	YES	–
4.1	Fixed format PDU description	YES	–
4.2	Object definitions in FAL management ASE	YES	–
4.3	Definition of objects used in Type 14 application access entity	YES	–
5	Transfer syntax	YES	–
5.1	Encoding of basic data types	YES	–
5.2	Encoding of Type 14 APDU header	YES	–
5.3	Encoding of FAL management entity service parameters	YES	–
5.4	Encoding of AAE Services	YES	–
6	Structure of FAL protocol state machines	YES	–
7	AP-Context state machine	YES	–
8	FAL management state machines	YES	–
9	Application access entity protocol machine	YES	–
10	Application relationship state machine	YES	–
11	DLL mapping protocol machine	YES	–

15.4.6 Performance indicator selection

15.4.6.1 Performance indicator overview

Table 178 provides an overview of CP 14/2 performance indicators.

Table 178 – CP 14/2: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	YES	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	–
Non-time-based synchronization accuracy	NO	–
Redundancy recovery time	YES	–

15.4.6.2 Performance indicator dependencies

Table 179 specifies the performance indacator dependencies for CP 14/2.

Table 179 – CP 14/2: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchron. accurancy	Redundency recovery time
Delivery time		YES	NO	YES	YES	NO	NO	NO
Number of end-stations	YES		NO	NO	NO	NO	NO	NO
Basic network topology	YES	NO		NO	NO	NO	YES	YES
Number of switches between end-stations	YES	NO	NO		NO	NO	YES	YES
Throughput RTE	NO	NO	NO	NO		YES	NO	NO
Non-RTE bandwidth	NO	NO	NO	NO	NO		YES	NO
Time synchronization accuracy	NO	YES	NO	YES	NO	NO		NO
Redundancy recovery time	YES	NO	YES	YES	NO	NO	NO	

15.4.6.2.1 Delivery Time

The performance indicator delivery time can be calculated by Formula (67).

$$DT = TStack\_S + TQueue\_S + TEthernet\_S + TTrf\_S \times Ndata + TCable \times LCable + TSwitch \times NSwitch + TStack\_R \quad (67)$$

where

DT	is the delivery time;
TStack_S	is the sender stack processing time;
TQueue_S	is the sender queuing delay, the max queue delay is equal to cycle time, the minimum queue delay is 0;
TEthernet_S	is the sender traversal time through MAC and Phy based on ISO/IEC 8802-3;
TTrf_S	is the transfer time for an octet;
Ndata	is the length in octets of complete Ethernet frame;
TCable	is the cable delay;
LCable	is the cable length;
TSwitch	is the Switch delay;
NSwitch	is the Number of switches between end-stations;
TStack_R	is the receiver stack processing time including Phy and MAC.

As shown in Formula (67),

- the number of end-stations influence DT with queue delay;
- the number of switches between end-stations influences DT. DT will be enlarged when the number of switches between end-stations increases;

- the throughput RTE influences DT. That is, DT will be enlarged due to queue delay when Throughput RTE increases. The max queue delay is equal to cycle time, and the minimum queue delay is 0.

15.4.6.2.2 Number of end-stations

If the delivery time is set to the bounded delivery time, then the maximum number of end-stations is restricted.

15.4.6.2.3 Basic network topology

The basic network topology is designed in linear, star, ring or daisy-chain according to the delivery time in application. If the delivery time is preset to the boundary delivery time, the basic network topology shall be set to a hierarchical star.

If the time synchronization accuracy is set to the minimum value, the basic network topology shall be set to a hierarchical star.

If redundancy recovery time is allowed to use rapid spanning tree algorithm according to IEEE 802.1D, then the basic network topology can be designed in linear, star, ring or daisy-chain.

15.4.6.2.4 Number of switches between end-stations

The number of switches between end-stations shall be designed to a minimum value so that delivery time, time synchronization accuracy and redundancy recovery accuracy meet the application requirements.

15.4.6.2.5 Throughput RTE and Non-RTE bandwidth

See 15.3.6.2.5.

15.4.6.2.6 Time synchronization accuracy

Time synchronization accuracy depends on synchronization cycle and switch delay. The synchronization cycle depends on the number of end-stations and the switch delay depends on the number of switches between end-stations.

15.4.6.2.7 Redundancy recovery time

The time to detect a failure depends on the number of switches between end-stations.

15.4.6.3 Consistent set of performance indicators

Table 180 specifies a consistent set of PI included in this profile.

Table 180 – CP 14/2: Consistent set of PIs

Performance indicator	Value	Constraints
Delivery Time	100 µs 500 µs	Without failure One frame lost
Number of end-stations	64	Star topology with switches connected
Number of switches between end-stations	4	–
Throughput RTE	1 536 000 octets/s	–
Non-RTE bandwidth	85 %	10 Mbit/s Ethernet (full duplex)
Time synchronization accuracy	$<$ 1 µs	–
Redundancy recovery time	$<$ 300 ms	Using IEEE 802.1D

15.5 Profile 14/3

15.5.1 Physical layer

The physical layer of the EPA profile is according to ISO/IEC 8802-3. EPA devices may use a data rate of 10 Mbit/s, 100 Mbit/s and higher. The topology shall be linear, star, ring or the combination of the above.

15.5.2 Data-link layer

The data-link layer shall be according to ISO/IEC 8802-3, IEEE 802-1D.

In addition, EPA Communication Scheduling Management Entity (ECSME) is defined on ISO/IEC 8802-3 data-link services are defined in IEC 61158-3-14, and data-link protocol to manage the deterministic communication in IEC 61158-4-14.

Table 181 defines the DLL service selection from IEC 61158-3-14 for profile 14/3.

Table 181 – CP 14/3: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	DL Service and concept	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DLL	YES	–
5	DL-management services	YES	–
5.1	Overview	Partial	Used when applicable
5.2	Non-periodic data annunciation	YES	–
5.3	EndofNonPeriodicDataSendingAnnunciation service	YES	–
5.4	DL-management for FRT applications	YES	–

Table 182 defines the DLL protocol selections from IEC 61158-4-14 for CP14/3.

Table 182 – CP 14/3: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations	Partial	Used when applicable
4	Overview of DL-protocol	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DL	YES	–
4.3	Structure of deterministic communication scheduling	YES	–
5	Procedure of deterministic communication scheduling	Partial	Used when applicable
5.1	Overview	Partial	Used when applicable
5.2	State transitions	Partial	Used when applicable
5.3	State table	Partial	Used when applicable
5.4	Function descriptions	Partial	Used when applicable
6	The structure and encoding of ECSME PDU	Partial	Used when applicable

15.5.3 Network Layer

Internet standards RFC 791 (IP), RFC 826 (ARP), RFC 792 (ICMP) and their amendments and successors can be used. For FRT applications, RFC 791 can be omitted to enhance real-time performance.

15.5.4 Transport Layer

Internet standards RFC 768 (UDP), RFC 793 (TCP) and their amendments and successors can be used. For FRT applications, RFC 768 can be omitted to enhance real-time performance.

15.5.5 Application layer

15.5.5.1 AL service selection

The application layer services for profile 14/3 are defined in IEC 61158-5-14. Table 183 specifies the clauses included in this profile.

Table 183 – CP 14/3: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Concepts	Partial	Used when applicable
5	Data type ASE	YES	–
6	Communication model specification	YES	–

15.5.5.2 AL protocol selection

The application layer protocols for profile 14/3 are defined IEC 61158-6-14. Table 184 specifies the clauses included in this profile.

Table 184 – CP 14/3: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Abstract syntax	YES	–
4.1	Fixed format PDU description	YES	–
4.2	Object definitions in FAL management ASE	YES	–
4.3	Definition of objects used in Type 14 application access entity	YES	–
5	Transfer syntax	YES	–
5.1	Encoding of basic data types	YES	–
5.2	Encoding of Type 14 APDU header	YES	–
5.3	Encoding of FAL management entity service parameters	YES	–
5.4	Encoding of AAE Services	YES	–
6	Structure of FAL protocol state machines	YES	–
7	AP-Context state machine	YES	–

Clause	Header	Presence	Constraints
8	FAL management state machines	YES	–
9	Application access entity protocol machine	YES	–
10	Application relationship state machine	YES	–
11	DLL mapping protocol machine	YES	–

15.5.6 Performance indicator selection

15.5.6.1 Performance indicator overview

Table 185 provides an overview of CP 14/3 performance indicators.

Table 185 – CP 14/3: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	–
Number of end stations	YES	–
Basic network topology	YES	–
Number of switches between end stations	YES	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	–
Non-time-based synchronization accuracy	NO	–
Redundancy recovery time	YES	–

15.5.6.2 Performance indicator dependencies

15.5.6.2.1 Dependency matrix

Table 186 specifies PI dependencies included in this profile.

Table 186 – CP 14/3: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end stations	Basic network topology	Number of switches between end stations	Throughput RTE	Non-RTE bandwidth	Time synchron. accurancy	Redundancy recovery time
Delivery time		YES	NO	YES	YES	NO	NO	NO
Number of end stations	YES		NO	NO	NO	NO	NO	NO
Basic network topology	YES	NO		NO	NO	NO	YES	YES
Number of switches between end stations	YES	NO	NO		NO	NO	YES	YES
Throughput RTE	NO	NO	NO	NO		YES	NO	NO
Non-RTE bandwidth	NO	NO	NO	NO	NO		YES	NO
Time synchronization accuracy	NO	YES	NO	YES	NO	NO		NO
Redundancy recovery time	YES	NO	YES	YES	NO	NO	NO	

15.5.6.2.2 Delivery Time

The performance indicator delivery time can be calculated by Formula (68).

$$DT = TStack\_S + TQueue\_S + TEthernet\_S + TTrf\_S \times Ndata + TCable \times LCable + TSwitch \times NSwitch + TStack\_R \quad (68)$$

where

DT	is the delivery time;
TStack_S	is the sender stack processing time;
TQueue_S	is the sender queuing delay;
TEthernet_S	is the sender traversal time through MAC and Phy based on ISO/IEC 8802-3;
TTrf_S	is the transfer time for an octet;
Ndata	is the length in octets of complete Ethernet frame;
TCable	is the cable delay;
LCable	is the cable length;
TSwitch	is the Switch delay;
NSwitch	is the Number of switches between end stations;
TStack_R	is the receiver stack processing time including Phy and MAC.

As shown in Formula (68):

- the number of end stations influence DT with queue delay;
- the number of switches between end stations influences DT. DT will be longer when the number of switches between end stations increases;
- the throughput RTE influences DT. That is, DT will be longer due to queue delay when Throughput RTE increases.

15.5.6.2.3 Number of end stations

If the delivery time is set to the bounded delivery time, then the maximum number of end stations is restricted.

15.5.6.2.4 Basic network topology

The basic network topology is designed in linear, star, ring or daisy-chain according to the delivery time in application.

If redundancy recovery time is allowed to use rapid spanning tree algorithm according to IEEE 802.1D, then the basic network topology can be designed in linear, star, ring or daisy-chain. For redundant ring topology, a single cable fault does not produce any failure, redundancy recovery time is zero.

15.5.6.2.5 Number of switches between end stations

The number of switches between end stations shall be designed to a minimum value so that delivery time, time synchronization accuracy and redundancy recovery accuracy meet the application demands.

15.5.6.2.6 Relation between Throughput RTE and Non-RTE bandwidth

The relation between Throughput RTE and Non-RTE bandwidth is specified in Formula (69).

$$NRTE\_BW = ((RateofEthernet - ThroughputRTE \times 8) / RateofEthernet) \times 100 \quad (69)$$

where

NRTE_BW	is the non-RTE bandwidth, in %;
RateofEthernet	is the Ethernet data rate in Mbit/s;
ThroughputRTE	is the RTE throughput in octets/s.

Throughput RTE can be calculated by Formula (70).

$$ThroughputRTE = (\sum (RTEData + TSData + RMData)) / s \quad (70)$$

where

ThroughputRTE	is the RTE throughput in octets/s;
RTEData	is the real-time data in octets;
TSData	is the time synchronization data in octets;
RMData	is the redundancy management data in octets.

15.5.6.2.7 Time synchronization accuracy

Time synchronization accuracy depends on synchronization cycle and switch delay. The synchronization cycle depends on the number of end stations and the switch delay depends on the number of switches between end stations.

15.5.6.2.8 Redundancy recovery time

The time to detect a failure is depends on the number of switches between end stations.

15.5.6.3 Consistent set of performance indicators

Table 187 specifies consistent set of PI included in this profile.

Table 187 – CP 14/3: Consistent set of PIs

performance indicator	Value	Constraints
Delivery time	100 µs 100 µs 200 µs	Star topology, no failure Linear topology, no failure Ring topology, no failure
Number of end stations	6	–
Number of switches between end stations	1 0 0	Star topology Linear topology Ring topology
Throughput RTE	3 840 000 octets/s	100 Mbit/s Ethernet (full-duplex)
Non-RTE bandwidth	0	–
Time synchronization accuracy	< 1 µs	–
Redundancy recovery time	n.a. n.a. 0 s	Star topology Linear topology Ring topology

Table 188 specifies consistent set of PI included in this profile.

Table 188 – CP 14/3: Consistent set of PIs

performance indicator	value	constraints
Delivery time	250 μs 250 μs 500 μs	Star topology, no failure Linear topology, no failure Ring topology, no failure
Number of end stations	6	
Number of switches between end stations	1 0 0	Star topology Linear topology Ring topology
Throughput RTE	1 536 000 octets/s	100 Mbit/s Ethernet (full duplex)
Non-RTE bandwidth	84 %	100 Mbit/s Ethernet (full duplex)
Time synchronization accuracy	< 1 μs	–
Redundancy recovery time	n.a. n.a. 0 s	Star topology Linear topology Ring topology

Table 189 specifies consistent set of PI included in this profile.

Table 189 – CP 14/3: Consistent set of PIs

performance indicator	value	Constraints
Delivery time	1 000 μs 1 000 μs 2 000 μs	Star topology, no failure Linear topology, no failure Ring topology, no failure
Number of end stations	80	–
Number of switches between end stations	3 0 0	Star topology Linear topology Ring topology
Throughput RTE	5 576 000 octets/s	100 Mbit/s Ethernet (full duplex)
Non-RTE bandwidth	40 %	100 Mbit/s Ethernet (full duplex)
Time synchronization accuracy	< 1 μs	–
Redundancy recovery time	300 ms n.a. 0	Star topology, IEEE 802.1D Linear topology Ring topology

15.6 Profile 14/4

15.6.1 Physical layer

The Physical Layer of the EPA profile is according to ISO/IEC 8802-3. EPA devices may use a data rate of 10 Mbit/s, 100 Mbit/s and higher. The topology shall be linear, star, ring or the combination of the above.

15.6.2 Data-link layer

The Data Link Layer shall be according to ISO/IEC 8802-3, IEEE 802-1D.

In addition, EPA Communication Scheduling Management Entity (ECSME) is defined on ISO/IEC 8802-3 data link services are defined in IEC 61158-3-14, and data link protocol to manage the deterministic communication in IEC 61158-4-14.

Table 190 defines the DLL service selection from IEC 61158-3-14 for profile 14/4.

Table 190 – CP 14/4: DLL service selection

Clause	Header	Presence	constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	DL Service and concept	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DLL	YES	–
5	DL-management services	YES	–
5.1	Overview	Partial	Used when applicable
5.2	Non-periodic data annunciation	YES	–
5.3	EndofNonPeriodicDataSendingAnnunciation service	YES	–
5.4	DL-management for FRT applications	–	–

Table 191 defines the DLL protocol selections from IEC 61158-4-14 for CP14/4

Table 191 – CP 14/4: DLL protocol selection

Clause	Header	Presence	constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations	Partial	Used when applicable
4	Overview of DL-protocol	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DL	YES	–
4.3	Structure of deterministic communication scheduling	YES	–
5	Procedure of deterministic communication scheduling	Partial	–
5.1	Overview	YES	–
5.2	State transitions	YES	–
5.3	State table	YES	–
5.4	Function descriptions	–	–
6	The structure and encoding of ECSME PDU	YES	–

15.6.3 Network layer

Internet standards RFC 791 (IP), RFC 826 (ARP), RFC 792 (ICMP) and their amendments and successors can be used.

15.6.4 Transport layer

Internet standard RFC 768 (UDP), RFC 793 (TCP) and their amendments and successors may be used. But for real-time applications, RFC 768 shall be used for field devices, bridges and master devices.

15.6.5 Application layer

15.6.5.1 AL service selection

The application layer services for profile 14/4 are defined in IEC 61158-5-14. Table 192 specifies the clauses included in this profile.

Table 192 – CP 14/4: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Concepts	Partial	Used when applicable
5	Data type ASE	YES	–
6	Communication model specification	YES	–

15.6.5.2 AL protocol selection

The application layer protocol for profile 14/4 is defined in IEC 61158-6-14. Table 193 specifies the clauses included in this profile.

Table 193 – CP 14/4: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Abstract syntax	YES	–
4.1	Fixed format PDU description	YES	–
4.2	Object definitions in FAL management ASE	YES	–
4.3	Definition of objects used in Type 14 application access entity	YES	–
5	Transfer syntax	YES	–
5.1	Encoding of basic data types	YES	–
5.2	Encoding of Type 14 APDU header	YES	–
5.3	Encoding of FAL management entity service parameters	YES	–
5.4	Encoding of AAE Services	YES	–
6	Structure of FAL protocol state machines	YES	–
7	AP-Context state machine	YES	–
8	FAL management state machines	YES	–
9	Application access entity protocol machine	YES	–
10	Application relationship state machine	YES	–
11	DLL mapping protocol machine	YES	–

15.6.6 Performance indicatior selection

15.6.6.1 Performance indicator overview

Table 194 provides an overview of CP 14/4 performance indicators.

Table 194 – CP 14/4: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	YES	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	–
Non-time-based synchronization accuracy	NO	–
Redundancy recovery time	YES	–

15.6.6.2 Performance indicator dependencies

specifies the performance indacator dependencies for CP 14/4.

Table 195 – CP 14/4: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchron. accurancy	Redundency recovery time
Delivery time		YES	NO	YES	YES	NO	NO	NO
Number of end-stations	YES		NO	NO	NO	NO	NO	NO
Basic network topology	YES	NO		NO	NO	NO	YES	YES
Number of switches between end-stations	YES	NO	NO		NO	NO	YES	YES
Throughput RTE	NO	NO	NO	NO		YES	NO	NO
Non-RTE bandwidth	NO	NO	NO	NO	NO		YES	NO
Time synchronization accuracy	NO	YES	NO	YES	NO	NO		NO
Redundancy recovery time	YES	NO	YES	YES	NO	NO	NO	

15.6.6.2.1 Delivery Time

The performance indicator delivery time can be calculated by Formula (71).

$$DT = TStack\_S + TQueue\_S + TEthernet\_S + TTrf\_S \times Ndata + TCable \times LCable + TSwitch \times NSwitch + TStack\_R \quad (71)$$

where

DT	is the delivery time;
TStack_S	is the sender stack processing time;
TQueue_S	is the sender queuing delay, the max queue delay is equal to cycle time, the minimum queue delay is 0;
TEthernet_S	is the sender traversal time through MAC and Phy based on ISO/IEC 8802-3;
TTrf_S	is the transfer time for an octet;
Ndata	is the length in octets of complete Ethernet frame;
TCable	is the cable delay;
LCable	is the cable length;
TSwitch	is the Switch delay;
NSwitch	is the Number of switches between end-stations;
TStack_R	is the receiver stack processing time including Phy and MAC.

As shown in Formula (71),

- the number of end-stations influence DT with queue delay;
- the number of switches between end-stations influences DT. DT will be enlarged when the number of switches between end-stations increases;
- the throughput RTE influences DT. That is, DT will be enlarged due to queue delay when Throughput RTE increases. The max queue delay is equal to cycle time, and the minimum queue delay is 0.

15.6.6.2.2 Number of end-stations

If the delivery time is set to the bounded delivery time, then the maximum number of end-stations is restricted.

15.6.6.2.3 Basic network topology

The basic network topology is designed in linear, star, ring or daisy-chain according to the delivery time in application. If the delivery time is preset to the boundary delivery time, the basic network topology shall be set to a hierarchical star.

If the time synchronization accuracy is set to the minimum value, the basic network topology shall be set to a hierarchical star.

If redundancy recovery time is allowed to use rapid spanning tree algorithm according to IEEE 802.1D, then the basic network topology can be designed in linear, star, ring or daisy-chain.

15.6.6.2.4 Number of switches between end-stations

The number of switches between end-stations shall be designed to a minimum value so that delivery time, time synchronization accuracy and redundancy recovery accuracy meet the application requirements.

15.6.6.2.5 Throughput RTE and Non-RTE bandwidth

See 15.3.6.2.5.

15.6.6.2.6 Time synchronization accuracy

Time synchronization accuracy depends on synchronization cycle and switch delay. The synchronization cycle depends on the number of end-stations and the switch delay depends on the number of switches between end-stations.

15.6.6.2.7 Redundancy recovery time

The time to detect a failure depends on the number of switches between end-stations.

15.6.6.3 Consistent set of performance indicators

Table 196 specifies a consistent set of PI included in this profile.

Table 196 – CP 14/4: Consistent set of PIs

Performance indicator	Value	Constraints
Delivery Time	100 µs 500 µs	Without failure One frame lost
Number of end-stations	6	Star topology with switches connected
Number of switches between end-stations	1	–
Throughput RTE	9 248 000 octets/s	–
Non-RTE bandwidth	25 %	100 Mbit/s Ethernet (full duplex)
Time synchronization accuracy	< 1 µs	–
Redundancy recovery time	< 300 ms	Using IEEE 802.1D

16 Communication Profile Family 15 (MODBUS-RTPS) – RTE communication profiles

16.1 General overview

Communication Profile Family 15 defines profiles based on ISO/IEC 8802-3, RFC 791 (IP), RFC 793 (TCP), RFC 768 (UDP), IEC 61158-5-15 and IEC 61158-6-15, which specify the communication system protocols commonly known as Modbus® [13] and Modbus TCP, and RTPS (Real-Time Publish-Subscribe).

In this part of IEC 61784, the following communication profiles are specified for CPF 15:

– Profile 15/1
  Is a profile using Modbus TCP
– Profile 15/2
  Is a profile using RTPS.

For both profiles the communication is assumed to be full-duplex, with network topologies built via switches.

13 Modbus is a trademark of Schneider Automation Inc registered in the United States of America and other countries. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trademark Modbus. Use of the trademark Modbus requires permission from Schneider Automation Inc.

These communication profiles can be active at the same time on the same device and network, and as such they do not constitute alternative profiles, but can provide complementary and concurrent functionality.

16.2 Profile 15/1

16.2.1 Physical layer

The physical layer of CP 15/1 is as specified in ISO/IEC 8802-3.

16.2.2 Data-link layer

The data-link layer of CP 15/1 is as specified in ISO/IEC 8802-3.

16.2.3 Application layer

16.2.3.1 General

The application layer of CP 15/1 is mapped on TCP (RFC 793), using TCP Port Number 502, registered with IANA, over IP (RFC 791), as described in IEC 61158-5-15 and IEC 61158-6-15.

16.2.3.2 AL service selection

The application layer services are defined in IEC 61158-5-15. Table 197 shows the subclauses included in this profile.

Table 197 – CP 15/1: AL service selection

Clause	Header	Presence	Constraints
Whole document	Application layer services definition (Type 15)	Partial	Subclauses qualified as Common or Client/Server

16.2.3.3 AL protocol selection

The application layer protocols are defined in IEC 61158-6-15. Table 198 shows the subclauses included in this profile.

Table 198 – CP 15/1: AL protocol selection

Clause	Header	Presence	Constraints
Whole document	Application layer protocol specification (Type 15)	Partial	Subclauses qualified as Common or Client/Server

16.2.4 Performance indicator selection

16.2.4.1 Performance indicator overview

Table 199 provides an overview of the CP 15/1 performance indicators.

Table 199 – CP 15/1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	YES	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	Provided with NTP (RFC 1305)
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	YES	–

16.2.4.2 Performance indicator dependencies

Table 200 provides the CP 15/1 performance indicator dependency matrix.

Table 200 – CP 15/1: PI dependency matrix

Dependent PI	Influencing PI								
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchron. accurancy	non time- based synchron. accurancy	Redundency recovery time
Delivery time		NO	YES 16.2.4.2.1 16.2.4.2.23	YES 16.2.4.2.23	NO	NO	NO	NO 16.2.4.2.2	YES 16.2.4.2.3
Number of end-stations	NO		NO 16.2.4.2.4	YES 16.2.4.2.5	NO	NO	NO	NO	NO
Basic network topology	NO	YES 16.2.4.2.6		YES 16.2.4.2.7	NO	NO	NO	NO	NO
Number of switches between end-stations	NO	YES 16.2.4.2.8	YES 16.2.4.2.9		NO	NO	NO	NO	NO
Throughput RTE	NO	NO	NO	NO		YES 16.2.4.2.10	NO	NO 16.2.4.2.11	YES 16.2.4.2.12
Non-RTE bandwidth	NO	NO	NO	NO	YES 16.2.4.2.13		NO	NO	YES 16.2.4.2.14
Time synchronization accuracy	NO	NO	YES 16.2.4.2.15	YES 16.2.4.2.16	NO	NO		NO	YES 16.2.4.2.17
Non-time-based synchronization accuracy	NO	NO	YES 16.2.4.2.18	YES 16.2.4.2.19	NO	NO	NO		YES 16.2.4.2.20
Redundancy recovery time	NO	NO	YES 16.2.4.2.21	YES 16.2.4.2.22	NO	NO	NO	NO	

16.2.4.2.1 Delivery time and basic network topology

The following network topologies are supported:

- Star
- Linear (embedded or bus)
- Ring
- Redundant ring
- Mesh

The network topology influences the delivery time indirectly by influencing the number of switches to be traversed and the queuing and directly when supporting redundancy, by reacting differently in case of failures.

CP 15/1 has no switch technology dependencies.

16.2.4.2.2 Delivery time and non-time-based synchronization accuracy

In a scan situation it may affect the delivery time of the response/confirmation, due to queues on switches. It does not affect non-scan situations.

16.2.4.2.3 Delivery time and redundancy recovery time

This dependency is applicable only when the network topology supports redundancy.

16.2.4.2.4 Number of end-stations and basic network topology

Indirect dependency bounded in practice by the number of switches that have to be traversed, given the same number of connected end-stations, for different topologies.

16.2.4.2.5 Number of end-stations and number of switches between end-stations

The number of end-stations, for a given topology, depends on the number and kind of switches: there must be enough switches with enough ports.

16.2.4.2.6 Basic network topology and number of end-stations

Some topologies, e.g. linear, have limits on the number of nodes.

16.2.4.2.7 Basic network topology and number of switches between end-stations

The realization of some topologies requires a minimum number of switches, with a minimum number of ports, given a number of end-stations.

16.2.4.2.8 Number of switches between end-stations and number of end-stations

For certain topologies, like linear, the number of switches between end-stations depends on the number of end-stations. Considering the limit on the number of ports per switch this dependency is generally present.

16.2.4.2.9 Number of switches between end-stations and basic network topology

Some topologies allow for fewer switches given a number of nodes, e.g. the star topology.

16.2.4.2.10 Throughput RTE and non-RTE bandwidth

The application is responsible for limiting non-RTE traffic, which can otherwise impact the throughput RTE.

16.2.4.2.11 Throughput RTE and non-time-based synchronization accuracy

In a scan situation the throughput may be affected, due to queues on switches. It is not affected in non-scan situations.

16.2.4.2.12 Throughput RTE and redundancy recovery time

There is throughput RTE disruption when recovery takes place.

16.2.4.2.13 Non-RTE bandwidth and throughput RTE

The application is responsible for limiting RTE traffic if Not-RTE bandwidth has to be made available.

16.2.4.2.14 Non-RTE bandwidth and redundancy recovery time

There is non-RTE bandwidth disruption when recovery takes place.

16.2.4.2.15 Time synchronization accuracy and basic network topology

Some topologies, e.g. linear, affect the NTP accuracy due to the presence of variable delays.

16.2.4.2.16 Time synchronization accuracy and number of switches between end-stations

Switches cause variable delays, affecting the NTP accuracy.

16.2.4.2.17 Time synchronization accuracy and redundancy recovery time

There is disruption when recovery takes place.

16.2.4.2.18 Non-time-based synchronization accuracy and basic network topology

Some topologies, e.g. the star topology, allow for a better non-time-based synchronization accuracy.

16.2.4.2.19 Non-time-based synchronization accuracy and number of switches between end-stations

Switches cause variable delays, affecting the accuracy.

16.2.4.2.20 Non-time-based synchronization accuracy and redundancy recovery time

There is disruption when recovery takes place.

16.2.4.2.21 Redundancy recovery time and basic network topology

The redundancy recovery time, when supported by the topology, is topology dependent.

16.2.4.2.22 Redundancy recovery time and number of switches between end-stations

The redundancy recovery time, when supported by the topology, is dependent on the number of switches.

16.2.4.2.23 Calculation of delivery time

The performance indicator delivery time can be calculated by Formula (72)

$$DT = STT\_s + N\_Sw \times TD\_Sw + (N\_Sw + 1) \times T\_wire \times D\_size + STT\_r \qquad (72)$$

where

DT	is the delivery time;
STT_s	is the stack traversal time of the sender;
N_Sw	is the number of switches between end-stations;
TD_Sw	is the time delay in switch;
T_wire	is the time per octet on a wire segment;
D_size	is the data size in octets;
STT_r	is the stack traversal time of the receiver.

The performance indicator delivery time, in case of one lost frame, can be calculated by Formula (73) :

$$DT\_lf = 2 \times DT + RTO \quad (73)$$

where

DT_lf	is the delivery time when a frame is lost;
DT	is as computed in Formula (72);
RTO	is the TCP retransmission time out parameter.

NOTE RTO is a dynamic parameter, computed with an algorithm configured using an initial value and a minimum value, see RFC 2988 (Computing TCP's Retransmission Timer). The configuration values of RTO differ between TCP implementations.

16.3 Profile 15/2

16.3.1 Physical layer

The physical layer of CP 15/2 is as specified in ISO/IEC 8802-3.

16.3.2 Data-link layer

The data-link layer of CP 15/2 is as specified in ISO/IEC 8802-3.

16.3.3 Application layer

16.3.3.1 General

The application layer of CP 15/2 is mapped on UDP (RFC 768), over IP (RFC 791), as described in IEC 61158-5-15 and IEC 61158-6-15.

CP 15/2 uses three UDP ports. The actual values can be configured in the field by setting the parameters 'portBaseNumber' and 'portGroupNumber' as from Formulae (74), (75) and (76). Implementations of CP 15/2 must support configuring these two parameters.

$$port1 = portBaseNumber + 10 \times portGroupNumber \quad (74)$$

$$port2 = 1 + portBaseNumber + 10 \times portGroupNumber \quad (75)$$

$$port3 = 2 + portBaseNumber + 10 \times portGroupNumber \quad (76)$$

The default configuration is to set the values portBaseNumber = 7400 and portGroupNumber = 0, which results in the use of ports 7400, 7401, and 7402. These ports are registered with IANA as:

- 7400 RTPS Discovery
- 7401 RTPS Data-Distribution User-Traffic
- 7402 RTPS Data-Distribution Meta-Traffic

16.3.3.2 AL service selection

The application layer services are defined in IEC 61158-5-15. Table 201 shows the subclauses included in this profile.

Table 201 – CP 15/2: AL service selection

Clause	Header	Presence	Constraints
Whole document	Application layer services definition (Type 15)	Partial	Subclauses qualified as Common or Publish/Subscribe

16.3.3.3 AL protocol selection

The application layer protocols are defined in IEC 61158-6-15. Table 202 shows the subclauses included in this profile.

Table 202 – CP 15/2: AL protocol selection

Clause	Header	Presence	Constraints
Whole document	Application layer protocol specification (Type 15)	Partial	Subclauses qualified as Common or Publish/Subscribe

16.3.4 Performance indicator selection

16.3.4.1 Performance indicator overview

Table 203 provides an overview of the CP 15/2 performance indicators.

Table 203 – CP 15/2: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	YES	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Redundancy recovery time	YES	–

16.3.4.2 Performance indicator dependencies

Table 204 provides the CP 15/2 performance indicator dependency matrix.

Table 204 – CP 15/2: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Redundancy recovery time
Delivery time		NO	YES 16.3.4.2.1 16.3.4.2.15	YES 16.3.4.2.15	NO	NO	YES 16.3.4.2.2
Number of end-stations	NO		NO 16.3.4.2.3	YES 16.3.4.2.4	NO	NO	NO
Basic network topology	NO	YES 16.3.4.2.5		YES 16.3.4.2.6	NO	NO	NO
Number of switches between end-stations	NO	YES 16.3.4.2.7	YES 16.3.4.2.8		NO	NO	NO
Throughput RTE	NO	NO	NO	NO		YES 16.3.4.2.9	YES 16.3.4.2.10
Non-RTE bandwidth	NO	NO	NO	NO	YES 16.3.4.2.11		YES 16.3.4.2.12
Redundancy recovery time	NO	NO	YES 16.3.4.2.13	YES 16.3.4.2.14	NO	NO	

16.3.4.2.1 Delivery time and basic network topology

The following network topologies are supported:

- Star
- Linear (embedded or bus)
- Ring
- Redundant ring
- Mesh

The network topology influences the delivery time indirectly by influencing the number of switches to be traversed and the queuing and directly when supporting redundancy, by reacting differently in case of failures.

CP 15/2 has no switch technology dependencies.

16.3.4.2.2 Delivery time and redundancy recovery time

This dependency is applicable only when the network topology supports redundancy.

16.3.4.2.3 Number of end-stations and basic network topology

Indirect dependency bounded in practice by the number of switches that have to be traversed, given the same number of connected end-stations, for different topologies.

16.3.4.2.4 Number of end-stations and number of switches between end-stations

The number of end-stations, for a given topology, depends on the number and kind of switches: there must be enough switches with enough ports.

16.3.4.2.5 Basic network topology and number of end-stations

Some topologies, e.g. linear, have limits on the number of nodes.

16.3.4.2.6 Basic network topology and number of switches between end-stations

The realization of some topologies requires a minimum number of switches, with a minimum number of ports, given a number of end-stations.

16.3.4.2.7 Number of switches between end-stations and number of end-stations

For certain topologies, like linear, the number of switches between end-stations depends on the number of end-stations. Considering the limit on the number of ports per switch this dependency is generally present.

16.3.4.2.8 Number of switches between end-stations and basic network topology

Some topologies allow for fewer switches given a number of nodes, e.g. the star topology.

16.3.4.2.9 Throughput RTE and non-RTE bandwidth

The application is responsible for limiting non-RTE traffic, which can otherwise impact the throughput RTE.

16.3.4.2.10 Throughput RTE and redundancy recovery time

There is throughput RTE disruption when recovery takes place.

16.3.4.2.11 non-RTE bandwidth and throughput RTE

The application is responsible for limiting RTE traffic if non-RTE bandwidth has to be made available.

16.3.4.2.12 not-RTE bandwidth and redundancy recovery time

There is non-RTE bandwidth disruption when recovery takes place.

16.3.4.2.13 Redundancy recovery time and basic network topology

The redundancy recovery time, when supported by the topology, is topology dependent.

16.3.4.2.14 Redundancy recovery time and number of switches between end-stations

The redundancy recovery time, when supported by the topology, is dependent on the number of switches.

16.3.4.2.15 Calculation of delivery time

The performance indicator delivery time can be calculated using the Formulae (77), (78) and (79).

$$STT\_s = STT\_s1 + SST\_s2 \times D\_size \tag{77}$$

where

STT_s	is the stack traversal time of the sender;
STT_s1	is the part of the stack traversal time of the sender that is independent of the data size;
STT_s2	is the part of the stack traversal time of the sender that depends linearly on the size of the data D_size; this is because the stack performs a memory copy so it is affected by the speed of the memory system;
D_size	is the data size in octets.

$$STT\_r = STT\_r1 + SST\_r2 \times D\_size \tag{78}$$

where

STT_r	is the stack traversal time of the receiver;
STT_r1	is the part of the stack traversal time of the receiver that is independent of the data size;
STT_r2	is the part of the stack traversal time of the receiver that depends linearly on the size of the data D_size; this is because the stack performs a memory copy so it is affected by the speed of the memory system;
D_size	is the data size in octets.

$$DT = STT\_s + N\_Sw \times TD\_Sw + (N\_Sw + 1) \times T\_wire \times D\_size + STT\_r \tag{79}$$

where

DT	is the delivery time;
STT_s	is the stack traversal time of the sender;
N_Sw	is the number of switches between end-stations;
TD_Sw	is the time delay in switch;
T_wire	is the time per octet on a wire segment;
D_size	is the data size in octets;
STT_r	is the stack traversal time of the receiver.

The performance indicator delivery time, in case of one lost frame, depends on how the communication between end-stations under consideration is configured:

a) best effort;

b) reliable periodic;

c) reliable with heartbeat.

If best effort, then the delivery time in case of a lost frame does not apply, since that frame is not retransmitted.

If reliable periodic then, in case of one lost frame, the performance indicator delivery time can be calculated by the Formula (80).

$$DT\_lfp = 2 \times DT + DT\_n + T \tag{80}$$

where

DT_lfp	is the delivery time when a frame is lost and the configuration is reliable periodic;
DT	is as computed in Formula (79);
DT_n	is the delivery time for the NACK message, computed again using Formula (79), but with a D_size of 16 octets;
T	is the period, which is a configured parameter.

NOTE 1 A typical value for the period T is 10 ms.

If reliable with heartbeat then, in case of one lost frame, the performance indicator delivery time can be calculated by the Formula (81)

$$DT\_lfh = 2 \times DT + DT\_n + H \qquad (81)$$

where

DT_lfh	is the delivery time when a frame is lost and the configuration is reliable with heartbeat;
DT	is as computed in Formula (79);
DT_n	is the delivery time for the NACK message, computed again using Formula (79), but with a D_size of 16 octets;
H	is the period of the heartbeat, which is a configured parameter.

NOTE 2 A typical value for the period heartbeat is between 100 ms and 1 s (it has a system monitoring role and does not carry any data).

17 Communication Profile Family 16 (SERCOS[14])- RTE communication profiles

17.1 General overview

Communication Profile Family 16 defines profiles based on IEC 61158 series, protocol Type 16 and Type 19.

The CPF 16 consists of three communication profiles (CP).

– Profile 16/1 (SERCOS I)

  This profile is based on fibre-media physical layers and operates at 2 Mbit/s and 4 Mbit/s. Refer to IEC 61784-1.

– Profile 16/2 (SERCOS II)

  This profile is similar to 16/1, but operates also at 8 Mbit/s and 16 Mbit/s, and provides for additional features. Refer to IEC 61784-1.

– Profile 16/3 (SERCOS III)

  This profile is based on ISO/IEC 8802-3 (Ethernet) MAC and physical layers; it provides again for additional features.

17.2 Profile 16/3 (SERCOS III)

17.2.1 Physical layer

The physical layer is based on standard Ethernet hardware according to ISO/IEC 8802-3. CP 16/3 (SERCOS III) devices shall use a data rate of 100 Mbit/s, and shall be connected in a ring or a line topology. Any combination of full-duplex, 100Base-TX with auto crossover function (wire, 2 twisted pairs), as well as 100Base-FX (optical fibre) may be used.

When using cables, they shall be rated Cat5e or better, and shielded in an appropriate way (FTP, STP or SFTP) depending upon EMC constraints.

[14] SERCOS and SERCOS interface are trade names of SERCOS International e.V. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

17.2.2 Data-link layer

17.2.2.1 General

CP 16/3 profile shall use standard Ethernet ISO/IEC 8802-3 frames tagged with the Ethertype 0x88CD.

17.2.2.2 DLL service selection

The data-link layer services are defined in IEC 61158-3-19. Table 205 shows the subclauses included in this profile.

Table 205 – CP 16/3: DLL service selection

Clause	Header	Presence	Constraints
Whole document	Data link protocol specification (Type 19)	YES	–

17.2.2.3 DLL protocol selection

The data-link layer protocols are defined in IEC 61158-4-19. Table 206 shows the subclauses included in this profile.

Table 206 – CP 16/3: DLL protocol selection

Clause	Header	Presence	Constraints
Whole document	Data link protocol specification (Type 19)	YES	–

17.2.3 Application layer

17.2.3.1 AL service selection

The application layer services are defined in IEC 61158-5-19. Table 207 shows the subclauses included in this profile.

Table 207 – CP 16/3: AL service selection

Clause	Header	Presence	Constraints
Whole document	Data link protocol specification (Type 19)	YES	–

17.2.3.2 AL protocol selection

The application layer protocol is defined in IEC 61158-6-19. Table 208 shows the subclauses included in this profile.

Table 208 – CP 16/3: AL protocol selection

Clause	Header	Presence	Constraints
Whole document	Data link protocol specification (Type 19)	YES	–

17.2.4 Performance indicator selection

17.2.4.1 Performance indicator overview

Table 209 gives an overview on the applicable performance indicators for CP 16/3.

Table 209 – CP 16/3: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	NO	Switches shall not be used
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	NO	–
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	YES	In the ring topology, a single permanent fault does not produce any failure. In this case, the recovery time is zero

17.2.4.2 Performance indicator dependencies

Table 210 gives an overview on the dependencies of the performance indicators.

Table 210 – CP 16/3: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	non time- based synchron. accurancy	Redundancy recovery time
Delivery time		YES 17.2.4.2.1	NO	YES 17.2.4.2.1	YES 17.2.4.2.1	NO	NO
Number of end-stations	YES		NO	YES	YES	NO	NO
Basic network topology	NO	NO		NO	NO	NO	NO
Throughput RTE	NO	NO	NO		YES 17.2.4.2.5	NO	NO
Non-RTE bandwidth	NO	NO	NO	YES 17.2.4.2.5		NO	NO
Non-time-based synchronization accuracy	NO	YES 17.2.4.2.6	NO	NO	NO		NO
Redundancy recovery time	NO	NO	YES 17.2.4.2.7	NO	NO	NO	

17.2.4.2.1 Calculation of delivery time

The performance indicator delivery time can be calculated by Formula (82).

$$DT = ct + STTs + STTr + fr \tag{82}$$

where

DT	is the delivery time;
ct	is the cycle_time (according to 17.2.4.2.2);
STTs	is the sender stack traversal time including Phy and MAC (according to 17.2.4.2.4);
STTr	is the receiver stack traversal time including Phy and MAC (according to 17.2.4.2.4);
fr	is the frame runtime (according to 17.2.4.2.3);
STT	is the stack traversal time including Phy and MAC .

Example:

Cycle_Time = 31,25 µs; Frame Runtime = 9 µs; STTs << 1 µs; STTt << 1 µs

Delivery time = 31,25 µs + 9 µs = 40,25 µs

17.2.4.2.2 Calculation of cycle time

CP 16/3 is a communication technology with fixed, discrete communication cycles. The cycle time is defined as multiples and submultiples of 250 µs according to Formula (83).

$$ct = \begin{cases} N \times 250\ \mu s\ \text{where}\ N \geq 1\ \text{and}\ N \leq 260\ 000 \\ \dfrac{250\ \mu s}{N}\ \text{where}\ N = 2,\ 4\ \text{or}\ 8 \end{cases} \tag{83}$$

where

ct	is the cycle_time configured for the network segment;
N	is an integer value.

This means that the cycle time may be selected between 31,25 µs and 65 ms. It may be shorter, but shall not be longer. In any case, the selected cycle time shall be greater than the minimum cycle time, as shown in Formula (84).

$$ct > mct \tag{84}$$

where

ct	is the cycle_time configured for the network segment;
mct	is the minimum cycle time (according to Formula (85)).

The minimum cycle time of an application depends on the number of CP 16/3 nodes, the amount of real-time data exchanged between these nodes and the number of Ethernet frames that are used to transport the amount of real-time data between these nodes.

The minimum cycle time can be calculated by Formula (85).

$$mct = tt \times data + st \times nf \tag{85}$$

where

mct	is the minimum_cycle_time;
tt	is the transfer time (80 ns/octet);
data	Is the data to be transmitted in one cycle (including the complete Ethernet frame);
st	is the separation time per frame;
nf	is the number of frames.

The number of frames is in a range between 2 and 8 depending on the amount of data to be transmitted and the number of nodes.

Example

Transfer time = 80 ns/octet (100 Mbit/s); data = 336 octets; separation time per frame = 1 µs; number of frames = 2

Minimum cycle time: mct = 80 ns × 336 octets + 1 µs × 2 = 26,88 µs + 2 µs = 28,88 µs

Selected cycle time: ct = 31,25 µs > 28,88 µs

17.2.4.2.3 Calculation of the frame runtime

The frame runtime depends on the cable delay and the propagation delay (signal delay) in the forwarding nodes. Forwarding nodes are intermediate nodes between the sending and receiving node in a ring or line topology.

The frame runtime can be calculated by Formula (86)).

$$fr = cd \times clt + \sum_{i=1}^{nn} pd_i \qquad (86)$$

where

fr	is the frame runtime;
cd	is the cable delay;
clt	is the total cable length;
nn	is the number of nodes;
pd	is the propagation delay (signal delay) of a forwarding node.

Example

Cable delay = 5 ns/m; cable length = 900 m; propagation delay = 0,5 µs; number of nodes = 9

Frame runtime = 5 ns/m × 900 m + 9 × 0,5 µs = 9,0 µs

17.2.4.2.4 Calculation of Sender and Receiver Stack Traversal Time

The sender and receiver stack traversal time are implementation specific and cannot be calculated by a formula. Real-time data is not moved through a sender and receiver stack. Instead the data is exchanged between the application and the communication controller by means of a shared memory which allows a fast and efficient access to the data.

17.2.4.2.5 Throughput RTE and non-RTE bandwidth

The throughput RTE and the non-RTE bandwidth are directly dependent on each other. When cycle times below 250 µs are configured (125 µs, 62,5 µs, 31,25 µs) only real-time data can be transmitted (non-RTE bandwidth = 0). For cycle times of 250 µs and higher, the share of non-RTE bandwidth in relation to the available bandwidth of 100 Mbit/s can be freely configured.

Example 1

Cycle time = 250 µs, time slot for real-time data: 125 µs, time slot IP channel: 125 µs

Non-RTE bandwidth = 50 %, throughput RTE < 50 Mbit/s

Example 2

Cycle time = 500 µs, time slot for real-time data: 125 µs, time slot IP channel: 375 µs

Non-RTE bandwidth = 75 %, throughput RTE < 25 Mbit/s

17.2.4.2.6 Non-time based synchronization accuracy

The synchronization accuracy depends on the accuracy of the Ethernet hardware which influences the exact point of time when the synchronization pattern is received by the node. The synchronization pattern is part of the MDT0 telegram which is sent once per communication cycle.

The accuracy can be calculated by Formula (87).

$$ac = ma + \sum_{i=1}^{nn-1} sa_i \quad (87)$$

where

ac	is the non-time based synchronization accuracy;
ma	is the synchronization accuracy of the master device;
sa	is the synchronization accuracy of one slave device;
nn	the number of nodes; (nn-1) is the number of slaves, in a line topology.

Example 1 Master device with hardware-based synchronization

ma = 50 ns, 10 slave devices each with a synchronization accuracy of 50 ns

nslave = 10 slave devices each with a synchronization accuracy of 50 ns (equivalent to 20 slaves in a ring configuration)

ac = 50 ns + 10 × 50 ns = 550 ns

Example 2 Master device with Standard Ethernet hardware and software-based synchronization

ma = 40 µs, 10 slave devices each with a synchronization accuracy of 50 ns

*n*slave = 10 slave devices each with a synchronization accuracy of 50 ns (equivalent to 20 slaves in a ring configuration)

ac = 40 µs + 10 × 50 ns = 40,5 µs

17.2.4.2.7 Redundancy recovery time

In the ring topology, a single permanent fault does not produce any failure. The ring is immediately split into two lines. In this case, the recovery time is zero.

17.2.4.3 Consistent set of performance indicators

Table 211 shows the consistent set of performance indicators for a scenario where the minimal cycle time of 31,25 µs is configured in a ring topology. In this scenario it is assumed that 9 end-stations (1 master end-station and 8 slave end-stations) are set up in such a way that each node produces and consumes up to 10 octets each including control and status words (4 octets each), that is 20 real-time octets per node.

Table 211 – CP 16/3: Consistent set of PIs with a minimum cycle time of 31,25 µs

Performance indicator	Value	Constraints
Delivery time	< 39,8 µs	Cable length between all end-stations 100 m (worst case) Cycle time set to 31,25 µs Frame runtime: 9 µs
Number of end-stations	≤ 9	1 master end-station, 8 slave end-stations
Number of switches between end-stations	0	Switches shall not be used
Throughput RTE	≤ 11 520 000 octets/s	≤ 10/10 real-time octets per slave end-station
Non-RTE bandwidth	0	For cycle times below 250 µs, non-RTE traffic is not supported
Non-time-based synchronization accuracy	< 1 µs or < 50 µs	< 1 µs (high performance synchronization), < 50 µs (low performance synchronization)
Redundancy recovery time	0	In the ring topology, a single permanent fault does not produce any failure. In this case, the recovery time is zero

Table 212 shows the consistent set of performance indicators for a scenario where the cycle time of 500 µs is configured in a ring topology. In this scenario it is assumed that 185 end-stations (1 master end-station and 184 slave end-stations) are set up in such a way that each node produces and consumes up to 10 octets each including control and status words (4 octets each), that is 20 real-time octets per node. Non-RTE traffic is not used.

Table 212 – CP 16/3: Consistent set of PIs with a cycle time of 500 µs (real-time only)

Performance indicator	Value	Constraints
Delivery time	< 677 µs	Cable length between all end-stations 100 m (worst case) Cycle time set to 500 µs Frame runtime: 185 µs
Number of end-stations	≤ 185	1 master end station, 184 slave end-stations
Number of switches between end-stations	0	Switches shall not be used
Throughput RTE	≤ 12 192 000 octets/s	≤ 10/10 real-time octets per slave end-station
Non-RTE bandwidth	0	In this scenario, non-RTE traffic is not configured although possible
Non-time-based synchronization accuracy	< 1 µs or < 50 µs	< 1 µs (high performance synchronization), < 50 µs (low performance synchronization)
Redundancy recovery time	0	In the ring topology, a single permanent fault does not produce any failure. In this case, the recovery time is zero

Table 213 shows the consistent set of performance indicators for a scenario where the cycle time of 500 µs is configured in a ring topology. In this scenario it is assumed that 139 end-stations (1 master end-station and 138 slave end-stations) are set up in such a way that each node produces and consumes up to 10 octets each including control and status word (4 octets each), that is 20 real-time octets per node. The non-RTE traffic is used and uses 25 % of the available bandwidth (slot for non-real-time data: 125 µs = 25 % of 500 µs).

Table 213 – CP 16/3: Consistent set of PIs with a cycle time of 500 μs (real-time and non-real-time)

Performance indicator	Value	Constraints
Delivery time	< 513 μs	Cable length between all end-stations 100 m (worst case) Cycle time set to 500 μs Frame runtime: 139 μs
Number of end-stations	≤ 139	1 master end-station, 138 slave end-stations
Number of switches between end-stations	0	Switches shall not be used
Throughput RTE	≤ 9 248 000 octets/s	≤ 10/10 real-time octets per slave end-station
Non-RTE bandwidth	≤ 3 125 000 octets/s	25 % of the bandwidth is used for non-RTE traffic (IP channel is 125 μs wide)
Non-time-based synchronization accuracy	< 1 μs or < 50 μs	< 1 μs (high performance synchronization), < 50 μs (low performance synchronization)
Redundancy recovery time	0	In the ring topology, a single permanent fault does not produce any failure. In this case, the recovery time is zero

Table 214 shows the consistent set of performance indicators for a scenario where the cycle time of 500 μs is configured in a ring topology. In this scenario it is assumed that 101 end-stations (1 master end-station and 100 slave end-stations) are set up in such a way that each end slave node produces 24 octets and consumes 8 octets, including control and status words respectively (4 octets each). Such a scenario fits particularly well to power drive system applications as described in the IEC 61800 series. The non-RTE traffic is used and uses 25 % of the available bandwidth (slot for non-real-time data: 125 μs = 25 % of 500 μs).

Table 214 – CP 16/3: Consistent set of PIs with non symmetrical data throughput and a cycle time of 500 μs (real-time and non-real-time)

Performance indicator	Value	Constraints
Delivery time	< 474 μs	Cable length between all end-stations 100 m (worst case) Cycle time set to 500 μs Frame runtime: 101 μs
Number of end-stations	≤ 101	1 master end-station, 100 slave end-stations
Number of switches between end-stations	0	Switches shall not be used
Throughput RTE	≤ 9 248 000 octets/s	≤ 10/10 real-time octets per slave end-station
Non-RTE bandwidth	≤ 3 125 000 octets/s	25 % of the bandwidth is used for non-RTE traffic (IP channel is 125 μs wide)
Non-time-based synchronization accuracy	< 1 μs or < 50 μs	< 1 μs (high performance synchronization), < 50 μs (low performance synchronization)
Redundancy recovery time	0	In the ring topology, a single permanent fault does not produce any failure. In this case, the recovery time is zero

18 Communication Profile Family 17(RAPIEnet) – RTE communication profiles

18.1 General overview

Communication Profile Family 17 (CPF 17) defines one communication profile based on the IEC 61158 series protocol Type 21. This profile corresponds to the communication system commonly known as RAPIEnet.

- Profile 17/1 (RAPIEnet)

This profile is based on ISO/IEC 8802-3 (Ethernet) MAC and physical layers and selections of AL, and DLL services and protocol definitions from the IEC 61158 series Type 21.

Table 215 shows the overview of RAPIEnet profile set.

Table 215 – CPF 17: Overview of profile sets

Layer	Profile 17/1
Application	IEC 61158-5-21, IEC 61158-6-21
Data-link	IEC 61158-3-21, IEC 61158-4-21
Physical	ISO/IEC 8802-3

18.2 Profile 17/1

18.2.1 Physical layer

The physical layer shall be according to IEEE 802.3.

NOTE IEEE 802.3 is a revised version of ISO/IEC 8802-3.

The data rate shall be at least 100 Mbit/s and full-duplex mode shall be used at least for one port.

The auto negotiation and crossover function (see IEEE 802.3) shall be used.

18.2.2 Datalink layer

18.2.2.1 DLL services selection

Table 216 specifies the DLL service selection within IEC 61158-3-21.

Table 216 – CP 17/1: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviations and conventions	Partial	If applicable
4	Data-link layer services and concepts	YES	–
5	Data-link management services	YES	–
6	MAC control service	YES	–
7	Ph-control service	YES	–

18.2.2.2 DLL protocol selection

Table 217 specifies the DLL protocol selection within IEC 61158-4-21.

Table 217 – CP 17/1: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols and abbreviations	Partial	If applicable
4	Overview of the data-link protocol	YES	–
5	General structure and encoding	YES	–
6	DLPDU structure and procedure	YES	–
7	DLE elements of procedure	YES	–
8	Constants and error codes	YES	–

18.2.3 Application layer

18.2.3.1 AL service selection

Table 218 specifies the AL service selection within IEC 61158-5-21.

Table 218 – CP 17/1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviations, and conventions	Partial	If applicable
4	Concepts	YES	–
5	Data type ASE	YES	–
6	Communication model specification	YES	–

18.2.3.2 AL protocol selection

Table 219 specifies the AL protocol selection within IEC 61158-6-21.

Table 219 – CP 17/1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviations, and conventions	Partial	If applicable
4	FAL syntax description	YES	–
5	Transfer Syntax	YES	–
6	FAL protocol state machines	YES	–
7	AP context state machine	YES	–
8	FAL service protocol machine	YES	–
9	AR protocol machine	YES	–
10	DLL mapping protocol machine	YES	–

18.2.4 Performance indicator selection

18.2.4.1 Performance indicator overview

Table 220 shows the performance indicators overview of CP 17/1.

Table 220 – CP 17/1: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	None
Number of end stations	YES	None
Basic network topology	YES	None
Number of switches between end stations	Not practically limited by the protocol	RAPIEnet nodes are 2-port switches
Throughput RTE	YES	None
Non-RTE bandwidth	YES	None
Time synchronization accuracy	YES	None
Non time-based synchronization accuracy	No	None
Redundancy recovery time	YES	None

18.2.4.2 Performance indicator dependencies

18.2.4.2.1 Performance indicator dependency matrix

Table 221 shows the dependencies between performance indicators for CP 17/1.

Table 221 – CP 17/1: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchron. accuracy	Redundancy recovery time
Delivery time		Yes	NO	Yes	NO	NO	NO
Number of end stations	YES		NO	NO	NO	NO	NO
Basic network topology	NO	NO		NO	NO	NO	YES
Throughput RTE	NO	NO	NO		YES	NO	NO
Non-RTE bandwidth	NO	NO	NO	YES		NO	NO
Time synchronization accuracy	NO	YES	NO	NO	NO		NO
Redundancy recovery time	NO	YES	YES	YES	NO	NO	

18.2.4.2.2 Delivery time

The delivery time for communication between two RTE end stations can be calculated by Formula (88).

$$T_{DELAY} = T_{SND} + T_{PKT} + T_{CPD} + \sum_{i=0}^{N} T_{NLD\_i} + T_{RCV} \qquad (88)$$

where

T_{DELAY}	is the delivery time in microseconds;
T_{SND}	is the sender stack traversal time including Phy and MAC in microseconds;
T_{PKT}	is the packet transmit time in microseconds, see Formula (89);
T_{CPD}	is the cable propagation delay time in microseconds, see formula (90);
T_{NLD_i}	is the node latency delay time of node i in microseconds, see formula (91);
T_{RCV}	is the receiver stack traversal time including Phy and MAC in microseconds;
N	is the number of nodes between sending and receiving end-stations.

The packet transmit time T_{PKT} can be calculated by Formula (89).

$$T_{PKT} = \frac{(APDUsize + POsize) \times 8}{LDR} \qquad (89)$$

where

T_{PKT}	is the packet transmit time in microseconds;
$APDUsize$	is the size of the application protocol data unit in octets;
LDR	is the link data rate in bit per seconds;
$POsize$	is the size of the protocol overhead in octets.

The cable propagation delay time T_{CPD} can be calculated by Formula (90).

$$T_{CPD} = T_{CPD/M} \times L_{TC} \qquad (90)$$

where

T_{CPD}	is the cable propagation delay time in microseconds;
$T_{CPD/M}$	is the cable propagation delay in nanoseconds per meter (depending on the characteristics of the selected cable);
L_{TC}	is the total cable length in meter.

The node latency delay time T_{NLD_i} can be calculated by Formula (91).

$$T_{NLD\_i} = T_{NPD\_i} + T_{PKT\_i} + \sum_{j=0}^{M} T_{TX\_PKT\_ij} \qquad (91)$$

where

T_{NLD_i}	is the node latency delay time of node i in microseconds;
T_{NPD_i}	is the node propagation delay time of node i in microseconds;
T_{PKT_i}	is the packet transmit time of node i in microseconds, see Formula (89);
$T_{TX\_PKT\_ij}$	is the packet transmit time of packet j in microseconds in the port transmit queue of node i in front on of this packet (depending on APDU size of node i) , see Formula (89);
M	is the number of packets in the port transmit queue of node i in front on of this packet.

18.2.4.2.3 Number of end stations

The maximum number of the end stations shall be 256.

18.2.4.2.4 Basic network topology

Basic network topology shall be a ring or a linear topology.

18.2.4.2.5 Redundancy recovery time

Redundancy recovery time of Media redundancy requires ring topology.

The traffic load in the ring shall be less than 90 %.

In case of copper media, the redundancy recovery time for communication between any two end stations is less than 160 ms,

In case of fiber optic media, the redundancy recovery time for communication between any two end stations is less than 10 ms.

18.2.4.2.6 Throughput RTE

Throughput RTE depends on the link data rate and protocol overhead. Throughput RTE for one direction of a CP xx/1 link operating can be calculated on the basis of Formula (92).

$$Throughput\_RTE = APDUsize \times (NF_{RTE/S} \leq NF_{E/S\_MAX}) \tag{92}$$

where

APDUsize	is the size of the application protocol data unit in octets;
$NF_{RTE/S}$	is the number of frames allowed to be sent per second for one RTE end station;
NF_{E/S_MAX}	is the maximum number of frames allowed to be sent per second for one end station, see Formula (93).

The maximum number of frames allowed to be sent per second for one end station NF_{E/S_MAX} can be calculated by Formula (93).

$$NF_{E/S\_MAX} = \frac{LDR}{(APDUsize + POsize) \times 8} \tag{93}$$

where

LDR	is the link data rate in mega bit per seconds;
APDUsize	is the size of the application protocol data unit in octets;
POsize	is the size of the protocol overhead in octets.

18.2.4.2.7 Non-RTE bandwidth

The time not occupied by RTE communication can be used for non-RTE communication. Non-RTE bandwidth can be calculated as shown below.

18.2.4.2.8 Relation between throughput RTE and non-RTE bandwidth

The total link bandwidth is limited by the end station throughput, which is the same as the end station maximum packet rate. The total link bandwidth is therefore a sum of end station RTE and non-RTE packet rates and can be calculated using Formula (94).

$$BW_{NRTE} = \frac{NF_{E/S\_MAX} - NF_{RTE/S}}{NF_{E/S\_MAX}} \times 100\% \qquad (94)$$

where

BW_{NRTE}	is the non-RTE bandwidth, in %.;
NF_{E/S_MAX}	is the maximum number of frames allowed to be sent per second for one end station;
$NF_{RTE/S}$	is the number of frames allowed to be sent per second for one RTE end station.

18.2.4.3 Consistent set of performance indicators

Parameters used for the calculation of Table 222 are shown in Table 223. All these parameters are the result of the described scenario and the related calculations of performance indicators.

Table 222 – Consistent set of PIs small size automation system

Performance indicator	Value	Constraints
Delivery Time	110 µs to 4 100 µs	Processing time is 10 µs, no failure
Number of end stations	256	–
Number of switches between end stations	0	RAPIEnet nodes are 2-port switches
Throughput RTE	0 octets/s to 5,55 x 10^6 octets/s	100 Mbit/s (full-duplex)
Non-RTE bandwidth	0 % to 100 %	–
Time synchronization accuracy	< 10 µs	–
Redundancy recovery time	n.a. < 160 ms < 10 ms	Linear topology Ring topology (100BASE-TX) Ring topology (100BASE-FX)

Table 223 – Parameters for Calculation of Consistent set of PIs

Parameter	Definition	Value
T_{SND}	Sender stack traversal time including Phy and MAC	50 µs
T_{RCV}	Receiver stack traversal time including Phy and MAC	50 µs
APDUsize	Size of the application protocol data	32 octets
LDR	Link Data Rate	100 Mbit/s
POsize	Size of the protocol overhead	40 octets
$T_{CPD/M}$	Cable propagation delay (depending on the characteristics of the selected cable)	5 ns/m
L_{TC}	Total cable length	100 m
T_{NPD}	Node propagation delay time	10 µs
N	Number of nodes between sending and receiving end-stations	Minimum: 0 Maximum: 254

19 Communication Profile Family 18 (SafetyNET p[15]) – RTE communication profiles

19.1 General overview

Communication Profile Family 18 defines profiles based on IEC 61158-3-22, IEC 61158-4-22, IEC 61158-5-22 and IEC 61158-6-22.

In this part of IEC 61784, the following communication profiles are specified for CPF 18.

– Profile 18/1

  This profile defines protocol and service selection for devices which utilize the communication model real time frame line (RTFL).

– Profile 18/2

  This profile defines protocol and service selection for devices which utilize the communication model real time frame network (RTFN).

19.2 Profile 18/1

19.2.1 Physical layer

The physical layer shall be based on standard Ethernet hardware according to ISO/IEC 8802-3.

CP 18/1 devices shall use a data rate of 100 Mbit/s and full-duplex transmission mode. A combination of full-duplex and 100Base-TX with auto crossover function (wire, 2 twisted pairs) should be used.

When using cables, they shall be rated Cat5e or better, and shielded in an appropriate way (FTP, STP or SFTP) depending upon EMC constraints.

19.2.2 Data link layer

Data link layer is described in IEC 61158-3-22 and IEC 61158-4-22. Table 224 specifies the use of the services included in this profile. Table 225 specifies the use of the protocol included in this profile.

Table 224 – CP 18/1: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Data-link layer services and concepts	–	–
4.1	Operating principle	YES	–
4.2	Communication models	–	–
4.2.1	Overview	YES	–
4.2.2	RTFL device reference model	YES	–
4.2.3	RTFN device reference model	NO	–
4.3	Topology	–	–

15 SafetyNET p is a trade name of the Pilz GmbH & Co. KG. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trade name holder or any of its products. Compliance to this profile does not require use of the trade name SafetyNET p. Use of the trade name SafetyNET p requires permission of the trade name holder.

Clause	Header	Presence	Constraints
4.3.1	RTFL topology	YES	–
4.3.2	RTFN topology	NO	–
4.4	Addressing	–	–
4.4.1	Overview	YES	–
4.4.2	RTFL device addressing	YES	–
4.4.3	RTFN device addressing	NO	–
4.5	Gateway	YES	–
4.6	Interaction models	–	–
4.6.1	Overview	YES	–
4.6.2	Producer-consumer	YES	–
4.6.3	Publisher-subscriber	NO	–
4.7	Synchronization concept	YES	–
5	Communication services	–	–
5.1	Overview	Partial	Only services selected by this CP
5.2	Communication management services	–	–
5.2.1	Overview	YES	–
5.2.2	RTFL-network verification	–	–
5.2.2.1	DL-Network verification service (NV)	YES	–
5.2.2.2	DL-RTFN scan network read service (RTFNSNR)	NO	–
5.2.3	Communication management	–	–
5.2.3.1	DL-RTFN connection establishment service (RTFNCE)	NO	–
5.2.3.2	DL-RTFN connection release service (RTFNCR)	NO	–
5.2.3.3	DL-RTFL control service (RTFLCTL)	YES	–
5.2.3.4	DL-RTFL configuration service (RTFLCFG)	YES	–
5.2.3.5	DL-Read configuration data service (RDCD)	YES	–
5.2.3.6	DL-RTFL configuration service 2 (RTFLCFG2)	YES	–
5.2.3.7	DL-Read configuration data service 2 (RDCD2)	YES	–
5.3	Cyclic data channel service (CDC)	YES	–
5.4	Message channel services (MSC)	YES	–
5.5	Time synchronization	–	–
5.5.1	DL-DelayMeasurement start service (DMS)	YES	–
5.5.2	DL-DelayMeasurement read service (DMR)	YES	–
5.5.3	DL-PCS configuration service (PCSC)	YES	–
5.5.4	DL-Sync master configuration service (SYNC_MC)	YES	–
5.5.5	DL-Sync start service (SYNC_START)	YES	–
5.5.6	DL-Sync stop service (SYNC_STOP)	YES	–
5.6	Media independent interface (MII) management services	YES	–

Table 225 – CP 18/1: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Overview of the DL-protocol	–	–
4.1	Operating principle	YES	–
4.2	Communication model	–	–
4.2.1	Overview	YES	–
4.2.2	RTFL device reference model	YES	–
4.2.3	RTFN device reference model	NO	–
4.3	Topology	–	–
4.3.1	RTFL topology	YES	–
4.3.2	RTFN topology	NO	–
4.4	DLPDU processing	–	–
4.4.1	Communication model RTFL	YES	–
4.4.2	Communication model RTFN	NO	–
4.5	General communication mechanisms	YES	–
4.6	Gateway	YES	–
4.7	Interaction models	–	–
4.7.1	Overview	YES	–
4.7.2	Producer-consumer	YES	–
4.7.3	Publisher-subscriber	NO	–
5	DLPDU structure	–	–
5.1	Overview	YES	–
5.2	Data types and encoding rules	YES	–
5.3	DLPDU identification	YES	–
5.4	General DLPDU structure	–	–
5.4.1	Type 22 DLPDU inside an ISO/IEC 8802-3 DLPDU	YES	–
5.4.2	Type 22 DLPDU inside a VLAN tagged ISO/IEC 8802-3 DLPDU	NO	–
5.4.3	Type 22 DLPDU inside an UDP DLPDU	NO	–
5.4.3	Type 22 DLPDU structure	YES	–
5.5	Communication management DLPDUs	–	–
5.5.1	RTFL-network verification DLPDUs	YES	–
5.5.2	RTFN scan network DLPDUs	NO	–
5.5.3	Identification data	YES	–
5.5.4	RTFN connection management DLPDU	NO	–
5.5.5	ID data	NO	–
5.5.6	RTFL control DLPDU	YES	–
5.5.7	RTFL configuration DLPDU	YES	–
5.6	Cyclic data channel (CDC) DLPDUs	–	–
5.6.1	Cyclic data channel line (CDCL) DLPDU	YES	–
5.6.2	Cyclic data channel network (CDCN) DLPDU	NO	–
5.7	Cyclic data channel (CDC) DLPDU data	YES	–
5.8	Message channel (MSC) DLPDUs	–	–
5.8.1	Message channel line (MSCL) DLPDU	YES	–
5.8.2	Message channel network (MSCN) DLPDU	NO	–
5.9	Message channel DLPDU data – MSC message transfer protocol (MSC-MTP)	YES	–

Clause	Header	Presence	Constraints
5.10	Time synchronization	YES	–
6	Telegram timing and DLPDU handling	–	–
6.1	Communication mechanism	–	–
6.1.1	Communication model RTFL	YES	–
6.1.2	Communication model RTFN	NO	–
6.2	Device synchronization	–	–
6.2.1	Communication model RTFL – precise clock synchronization	YES	–
6.2.2	Communication model RTFN	NO	–
7	Type 22 protocol machines	–	–
7.1	RTFL device protocol machines	YES	–
7.2	RTFN device protocol machines	NO	–
7.3	Message channel – message transfer protocol (MSC-MTP)	YES	–

19.2.3 Application layer

Application layer is described in IEC 61158-5-22 and IEC 61158-6-22. Table 226 specifies the use of the services included in this profile. Table 227 specifies the use of the protocol included in this profile.

Table 226 – CP 18/1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Concepts	–	–
4.1	Common concepts	YES	–
4.2	Type specific concepts	–	–
4.2.1	Operating principle	YES	–
4.2.2	Communication model overview	–	–
4.2.2.1	Overview	YES	–
4.2.2.2	Communication model RTFL	YES	–
4.2.2.3	Communication model RTFN	NO	–
4.2.3	Application layer element description	YES	–
4.2.4	Producer-consumer interaction	YES	–
4.2.5	Device reference models	–	–
4.2.5.1	RTFL device reference model	YES	–
4.2.5.2	RTFN device reference model	NO	–
5	Data type ASE	YES	–
6	Communication model specification	–	–
6.1	Application service elements (ASEs)	–	–
6.1.1	CeS ASE	YES	–
6.1.2	ISO/IEC 8802-3 DLPDU communication ASE	YES	–
6.1.3	Management ASE	YES	–
6.2	Application relationships (ARs)	–	–
6.2.1	Overview	YES	–
6.2.2	Point-to-point network-scheduled unconfirmed producer-consumer AREP	YES	–
6.2.3	Point-to-multipoint network-scheduled unconfirmed producer-consumer AREP	YES	–

Clause	Header	Presence	Constraints
6.2.4	Point-to-point network-scheduled confirmed client/server AREP	YES	–
6.2.5	Point-to-point user-triggered confirmed client/server AREP	NO	–
6.2.6	AR classes	Partial	According to the present ARs
6.2.7	FAL services by AREP class	Partial	According to the present ARs
6.2.8	Permitted FAL services by AREP role	Partial	According to the present ARs

Table 227 – CP 18/1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Application layer protocol specification	–	–
4.1	Operating principle	YES	–
4.2	Device reference models	–	–
4.2.1	RTFL device reference model	YES	–
4.2.2	RTFN device reference model	NO	–
4.3	Application layer structure	YES	–
5	FAL syntax description	YES	–
6	FAL protocol state machines	YES	–
7	AP-context state machine	YES	–
8	FAL service protocol machine (FSPM)	YES	–
9	Application layer state machine (ALSM)	YES	–
10	DLL mapping protocol machine (DMPM)	YES	–

19.2.4 Performance indicator selection

19.2.4.1 Performance indicator overview

Table 228 gives an overview of the performance indicator usage.

Table 228 – CP 18/1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	None
Number of RTE end-stations	YES	None
Basic network topology	YES	Hierarchical star and linear topology
Number of switches between RTE end-stations	YES	For highest performance usage of switches shall be omitted
Throughput RTE	YES	None
Non-RTE bandwidth	YES	None
Time synchronization accuracy	YES	None
Non-time-based synchronization accuracy	NO	–
Redundancy recovery time	NO	–

19.2.4.2 Performance indicator dependencies

Table 229 specifies the dependencies of the performance indicators (row) from the performance indicators (column).

Table 229 – CP 18/1: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Number of switches between RTE end-stations	Throughput RTE	Non-RTE bandwidth	Time synchronization accuracy
Delivery time		YES 19.2.4.5	YES 19.2.4.6	YES 19.2.4.7	YES 19.2.4.8	NO	NO
Number of end-stations	NO		NO	NO	NO	NO	YES 19.2.4.9
Basic network topology	NO	NO		YES 19.2.4.10	NO	NO	YES 19.2.4.11
Number of switches between RTE end-stations	NO	NO	YES 19.2.4.10		NO	NO	YES 19.2.4.13
Throughput RTE	NO	NO	NO	NO		YES 19.2.4.14	NO
Non-RTE bandwidth	NO	NO	NO	NO	YES 19.2.4.14		NO
Time synchronization accuracy	NO	YES 19.2.4.9	YES 19.2.4.11	YES 19.2.4.13	NO	NO	

19.2.4.3 Delivery time calculation

The performance indicator delivery time for a linear topology and a star topology can be calculated by Formula (95).

$$t_D = t_{cyc} + t_{STsrc} + t_{data} + t_{CD} * (l_F + l_B) + \sum_{i=1}^{NoDoF} \left(t_{pd}(i) + t_{SW}(i)\right) + \sum_{i=1}^{NoDoB} \left(t_{pd}(i) + t_{SW}(i)\right) + t_{ST\sin k} \qquad (95)$$

where

tD	is the delivery time;
tcyc	is the cycle time of the communication system ($t_{cycle} \geq t_{data}$);
tSTsrc	is the stack traversal time including data-link layer and physical layer of the source;
tdata	is the time to transmit all Real-time DLPDU for one cycle;
tCD	is the cable delay (4,5 ns/m to 5 ns/m);
lF	is the distance along the cable in meters which is passed by the packed from source to last device of the logical line;
lB	is the distance along the cable in meters which is passed by the packed from last device of the logical line to sink;
tpd	is the propagation delay of a device in forward or backward direction;
tSW	is the delay caused by switching procedure;
NoDoF	is the number of succeeding devices on forward direction from the source to the last device of the logical line;
NoDoB	is the number of succeeding devices on backward direction from the last device of the logical line to the sink;
tSTsink	is the stack traversal time including data-link layer and physical layer of the sink.

NOTE 1 In the case of a linear topology the time factor t_{SW} has the value 0.

NOTE 2 The distance in each direction is affected by the number of switching devices within the network topology.

19.2.4.4 Basic network topology

The basic network topologies supported by this profile are hierarchical star or linear topology. It is highly recommended to use linear topology to reach highest performance. For both basic network topologies this profile establishes a logical line topology by appropriate addressing within devices. For detailed information refer to IEC 61158-4-22.

19.2.4.5 Delivery time dependency on number of end-stations

The number of end-stations typically influences the amount of data, thus the time to transmit the data DLPDU as well as the sum of propagation delays. Furthermore the number of devices on forward and backward direction is influenced and hence the delivery time as described in Formula (95).

19.2.4.6 Delivery time dependency on basic network topology

The delivery time depends on the amount of signal propagation delays within a network which are introduced by a given network topology. The network topology dependent parameters in terms of additional delay times are considered in Formula (95).

19.2.4.7 Delivery time dependency on number of switches between RTE end-stations

The delivery time depends on the amount of signal propagation delays within a network which are introduced by switches between RTE end-stations. The switch dependent parameters in terms of additional delay times are considered in Formula (95).

19.2.4.8 Delivery time dependency on throughput RTE

The delivery time depends on throughput RTE via data amount and cycle time. Throughput RTE can be adapted by changing the parameters data amount and cycle time, whereas the minimal reachable cycle time depends highly on the amount of data to be transferred. If throughput RTE is increased by increasing the amount of data transferred within one cycle, the delivery time is increased. An increase of throughput RTE by reducing the cycle time decreases the delivery time. Throughput RTE can be increased by an adequate adjustment of both parameters without influencing the delivery time as described in Formula (95).

19.2.4.9 Relation between number of end-stations and time synchronization accuracy

The number of end-stations influences the accuracy of time synchronization and vice versa.

19.2.4.10 Relation between basic network topology and number of switches between RTE end-stations

The usage of switches is restricted to hierarchical star topology.

19.2.4.11 Relation between basic network topology and time synchronization accuracy

The usage of switches (for example to build up a hierarchical star topology) reduces the reachable accuracy of time synchronization of devices.

19.2.4.12 Relation between number of end-stations and time synchronization accuracy

The number of end-stations influences the accuracy of time synchronization and vice versa.

19.2.4.13 Relation between number of switches between RTE end-stations and time synchronization accuracy

Accuracy of time synchronization is the maximum jitter between device clocks. The usage of switches reduces the reachable accuracy of time synchronization of devices.

19.2.4.14 Relation between throughput RTE and non-RTE bandwidth

The non-RTE bandwidth is the difference between overall bandwidth and the RTE throughput (RTE overhead included) hence both values influence each other.

19.3 Profile 18/2

19.3.1 Physical layer

The physical layer shall be based on standard Ethernet hardware according to ISO/IEC 8802-3.

19.3.2 Data link layer

Data link layer is described in IEC 61158-3-22 and IEC 61158-4-22. Table 230 specifies the use of the services included in this profile. Table 231 specifies the use of the protocol included in this profile.

Table 230 – CP 18/2: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Data-link layer services and concepts	–	–
4.1	Operating principle	YES	–
4.2	Communication models	–	–
4.2.1	Overview	YES	–
4.2.2	RTFL device reference model	NO	–
4.2.3	RTFN device reference model	YES	–
4.3	Topology	–	–
4.3.1	RTFL topology	NO	–
4.3.2	RTFN topology	YES	–
4.4	Addressing	–	–
4.4.1	Overview	YES	–
4.4.2	RTFL device addressing	NO	–
4.4.3	RTFN device addressing	YES	–
4.5	Gateway	YES	–
4.6	Interaction models	–	–
4.6.1	Overview	YES	–
4.6.2	Producer-consumer	NO	–
4.6.3	Publisher-subscriber	YES	–
4.7	Synchronization concept	YES	–
5	Communication services	–	–
5.1	Overview	Partial	Only services selected by this CP
5.2	Communication management services	–	–
5.2.1	Overview	YES	–
5.2.2	RTFL-network verification	–	–
5.2.2.1	DL-Network verification service (NV)	NO	–

Clause	Header	Presence	Constraints
5.2.2.2	DL-RTFN scan network read service (RTFNSNR)	YES	–
5.2.3	Communication management	–	–
5.2.3.1	DL-RTFN connection establishment service (RTFNCE)	YES	–
5.2.3.2	DL-RTFN connection release service (RTFNCR)	YES	–
5.2.3.3	DL-RTFL control service (RTFLCTL)	NO	–
5.2.3.4	DL-RTFL configuration service (RTFLCFG)	NO	–
5.2.3.5	DL-Read configuration data service (RDCD)	NO	–
5.2.3.6	DL-RTFL configuration service 2 (RTFLCFG2)	NO	–
5.2.3.7	DL-Read configuration data service 2 (RDCD2)	NO	–
5.3	Cyclic data channel service (CDC)	YES	–
5.4	MSC services	YES	–
5.5	Time synchronization	–	–
5.5.1	DL-DelayMeasurement start service (DMS)	NO	–
5.5.2	DL-DelayMeasurement read service (DMR)	NO	–
5.5.3	DL-PCS configuration service (PCSC)	NO	–
5.5.4	DL-Sync master configuration service (SYNC_MC)	YES	–
5.5.5	DL-Sync start service (SYNC_START)	YES	–
5.5.6	DL-Sync stop service (SYNC_STOP)	YES	–
5.6	Media independent interface (MII) management services	NO	–

Table 231 – CP 18/2: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	DL-protocol overview	–	–
4.1	Operating principle	YES	–
4.2	Communication model	–	–
4.2.1	Overview	YES	–
4.2.2	RTFL device reference model	NO	–
4.2.3	RTFN device reference model	YES	–
4.3	Topology	–	–
4.3.1	RTFL topology	NO	–
4.3.2	RTFN topology	YES	–
4.4	DLPDU processing	–	–
4.4.1	Communication model RTFL	NO	–
4.4.2	Communication model RTFN	YES	–
4.5	General communication mechanisms	YES	–
4.6	Gateway	YES	–
4.7	Interaction models	–	–
4.7.1	Overview	YES	–
4.7.2	Producer-consumer	NO	–
4.7.3	Publisher-subscriber	YES	–
5	DLPDU structure	–	–
5.1	Overview	YES	–

Clause	Header	Presence	Constraints
5.2	Data types and encoding rules	YES	–
5.3	DLPDU identification	YES	–
5.4	General DLPDU structure	YES	–
5.5	Communication management DLPDUs	–	–
5.5.1	RTFL-network verification DLPDUs	NO	–
5.5.2	RTFN scan network DLPDUs	YES	–
5.5.3	Identification data	YES	–
5.5.4	RTFN connection management DLPDU	YES	–
5.5.5	ID data	YES	–
5.5.6	RTFL control DLPDU	NO	–
5.5.7	RTFL configuration DLPDU	NO	–
5.6	Cyclic data channel (CDC) DLPDUs	–	–
5.6.1	Cyclic data channel line (CDCL) DLPDU	NO	–
5.6.2	Cyclic data channel network (CDCN) DLPDU	YES	–
5.7	Cyclic data channel (CDC) DLPDU data	YES	–
5.8	Message channel (MSC) DLPDUs	–	–
5.8.1	Message channel line (MSCL) DLPDU	NO	–
5.8.2	Message channel network (MSCN) DLPDU	YES	–
5.9	Message channel DLPDU data – MSC message transfer protocol (MSC-MTP)	YES	–
5.10	Time synchronization	–	–
5.10.1	DelayMeasurement start	NO	–
5.10.2	DelayMeasurement read	NO	–
5.10.3	PCS configuration	NO	–
5.10.4	Time synchronization service	YES	–
6	Telegram timing and DLPDU handling	–	–
6.1	Communication mechanism	–	–
6.1.1	Communication model RTFL	NO	–
6.1.2	Communication model RTFN	YES	–
6.2	Device synchronization	–	–
6.2.1	Communication model RTFL – precise clock synchronization	NO	–
6.2.2	Communication model RTFN	YES	–
7	Type 22 protocol machines	–	–
7.1	RTFL device protocol machines	NO	–
7.2	RTFN device protocol machines	YES	–
7.3	Message channel – message transfer protocol (MSC-MTP)	YES	–

19.3.3 Application layer

Application layer is described in IEC 61158-5-22 and IEC 61158-6-22. Table 232 specifies the use of the services included in this profile. Table 233 specifies the use of the protocol included in this profile.

Table 232 – CP 18/2: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Concepts	–	–
4.1	Common concepts	YES	–
4.2	Type specific concepts	–	–
4.2.1	Operating principle	YES	–
4.2.2	Communication model overview	–	–
4.2.2.1	Overview	YES	–
4.2.2.2	Communication model RTFL	NO	–
4.2.2.3	Communication model RTFN	YES	–
4.2.3	Application layer element description	YES	–
4.2.4	Producer-consumer interaction	YES	–
4.2.5	Device reference models	–	–
4.2.5.1	RTFL device reference model	NO	–
4.2.5.2	RTFN device reference model	YES	–
5	Data type ASE	YES	–
6	Communication model specification	–	–
6.1	Application service elements (ASEs)	–	–
6.1.1	CeS ASE	YES	–
6.1.2	ISO/IEC 8802-3 DLPDU communication ASE	NO	–
6.1.3	Management ASE	YES	–
6.2	Application relationships (ARs)	–	–
6.2.1	Overview	YES	–
6.2.2	Point-to-point network-scheduled unconfirmed producer-consumer AREP	YES	–
6.2.3	Point-to-multipoint network-scheduled unconfirmed producer-consumer AREP	YES	–
6.2.4	Point-to-point network-scheduled confirmed client/server AREP	NO	–
6.2.5	Point-to-point user-triggered confirmed client/server AREP	YES	–
6.2.6	AR classes	Partial	According to the present ARs
6.2.7	FAL services by AREP class	Partial	According to the present ARs
6.2.8	Permitted FAL services by AREP role	Partial	According to the present ARs

Table 233 – CP 18/2: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Application layer protocol specification	–	–
4.1	Operating principle	YES	–
4.2	Device reference models	–	–
4.2.1	RTFL device reference model	NO	–
4.2.2	RTFN device reference model	YES	–
4.3	Application layer structure	YES	–
5	FAL syntax description	–	–
5.1	Introduction and coding principles	YES	–
5.2	Data type encoding	YES	–
5.3	CeS encoding	YES	–
5.4	ISO/IEC 8802-3 DLPDU communication	NO	–
5.5	Management encoding	YES	–
6	FAL protocol state machines	YES	–
7	AP-context state machine	YES	–
8	FAL service protocol machine (FSPM)	YES	–
9	Application layer state machine (ALSM)	YES	–
10	DLL mapping protocol machine (DMPM)	YES	–

19.3.4 Performance indicator selection

19.3.4.1 Performance indicator overview

Table 234 gives an overview of the performance indicator usage.

Table 234 – CP 18/2: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	None
Number of RTE end-stations	YES	None
Basic network topology	YES	Hierarchical star topology
Number of switches between RTE end-stations	YES	None
Throughput RTE	YES	None
Non-RTE bandwidth	YES	None
Time synchronization accuracy	YES	Requires switches capable to function as IEC 61588:2009 boundary clocks
Non-time-based synchronization accuracy	NO	–
Redundancy recovery time	NO	–

19.3.4.2 Performance indicator dependencies

Table 235 specifies the dependencies of the performance indicators (row) from the performance indicators (column).

Table 235 – CP 18/2: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Number of switches between RTE end-stations	Throughput RTE	Non-RTE bandwidth	Time synchronization accuracy
Delivery time		NO	NO	YES 19.3.4.4	NO	NO	NO
Number of end-stations	NO		NO	YES 19.3.4.5	NO	NO	NO
Basic network topology	NO	NO		NO	NO	NO	NO
Number of switches between RTE end-stations	NO	NO	NO		NO	NO	YES 19.3.4.6
Throughput RTE	NO	NO	NO	NO		YES 19.3.4.7	NO
Non-RTE bandwidth	NO	NO	NO	NO	YES 19.3.4.7		NO
Time synchronization accuracy	NO	NO	NO	YES 19.3.4.6	NO	NO	

19.3.4.3 Delivery time calculation

The performance indicator delivery time for a linear topology (physical line) can be calculated by Formula (96).

$$t_D = t_{cyc} + t_{STsrc} + t_{data} + t_{CD} * l_C + \sum_{i=1}^{NoS} t_{SW}(i) + t_{ST\,\sin k} \qquad (96)$$

where

tD	is the delivery time;
tcyc	is the cycle time of the communication relation ($t_{cycle} \geq t_{data}$);
tSTsrc	is the stack traversal time of the source;
tdata	is the time to transmit the packet containing the APDU;
tCD	is the cable delay (4,5 ns/m to 5 ns/m);
lC	is the cable length in m from source to sink;
tSW	is the delay time of the switch;
NoS	is the number of switches between source and sink.

NOTE 1 In the case of event-driven communication the time factor t_{cyc} has the value 0.

NOTE 2 The time behavior of switching devices is device-dependent.

19.3.4.4 Delivery time dependence on number of switches between RTE end-stations

The delivery time depends on the amount of signal propagation delays within a network which are introduced by switches between RTE end-stations. The switch dependent parameters in terms of additional delay times are considered in Formula (96).

19.3.4.5 Number of end-stations dependence on number of switches between RTE end-stations

A hierarchical star topology can be extended by additional switches, thus the number of RTE end-stations can be increased.

19.3.4.6 Relation between number of switches between RTE end-stations and time synchronization accuracy

Accuracy of time synchronization is the maximum jitter between device clocks. In order to achieve accuracy in a star network, it is necessary to use switches containing IEC 61588:2009 boundary clocks.

19.3.4.7 Relation between throughput RTE and non-RTE bandwidth

The non-RTE bandwidth is the difference between overall bandwidth and the RTE throughput (RTE overhead included) hence both values influence each other.

20 Communication Profile Family 8 (CC-Link) – RTE communication profiles

20.1 General overview

Communication Profile Family 8 defines profiles based on ISO/IEC 8802-3, IEC 61158-5-23 and IEC 61158-6-23, which specify the communication system protocols commonly known as CC-Link IE[16].

In this part of IEC 61784 the following communication profiles are specified for CPF 8:

– Profile 8/4
  a profile using fiber optic cable in a ring topology (CC-Link IE Control Network)
– Profile 8/5
  a profile using copper cable in linear and star topologies (CC-Link IE Field Network).

20.2 Profile 8/4

20.2.1 Physical layer

The physical layer of CP 8/4 is as specified in ISO/IEC 8802-3.

The bit rate shall be 1 000 Mbit/s. The full duplex and the auto negotiation function shall not be used.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-8.

20.2.2 Data link layer

The data link layer of CP 8/4 is as specified in ISO/IEC 8802-3.

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[16] CC-Link™ and CC-Link IE™ are trade names of Mitsubishi Electric Co.. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by IEC of the trade name holder or any of its products. Compliance to this standard does not require use of the trade names CC-Link™ or CC-Link IE™. Use of the trade names CC-Link™ or CC-Link IE™ requires permission of CC-Link Partner Association.

20.2.3 Application layer

20.2.3.1 AL service selection

Application Layer services are defined in IEC 61158-5-23. Table 236 shows the subclauses included in this profile.

Table 236 – CP 8/4: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviated terms and conventions	YES	–
4	Concept	YES	–
5	Data type ASE	YES	–
6	Communication model specification	–	–
6.1	Communication model	YES	–
6.2	ASE	–	–
6.2.1	Overview type C	YES	–
6.2.2	Overview type F	NO	–
6.2.3	Cyclic data ASE type C	YES	–
6.2.4	Cyclic data ASE type F	NO	–
6.2.5	Acyclic data ASE type C	YES	–
6.2.6	Acyclic data ASE type F	NO	–
6.2.7	Management ASE	YES	–
6.2.8	Synchronization ASE	NO	–
6.2.9	Measurement ASE	YES	–
6.3	AR Type C	YES	–
6.4	AR Type F	NO	–

20.2.3.2 AL protocol selection

Application Layer protocols are defined in IEC 61158-6-23. Table 237 shows the subclauses included in this profile.

Table 237 – CP 8/4: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviated terms and conventions	YES	–
4	FAL syntax description	–	–
4.1	FALPDU type C abstract syntax	YES	–
4.2	FALPDU type F abstract syntax	NO	–
4.3	Data assignmentds for type C	YES	–
4.4	Data assignmentds for type F	NO	–
5	FAL transfer syntax	–	–
5.1	Encoding rules	YES	–
5.2	FALPDU type C elements encoding	YES	–
5.3	FALPDU type F elements encoding	NO	–
6	Structure of the FAL protocol state machine	YES	–
7	FAL service protocol machine (FSPM)	–	–
7.1	Overview	YES	–
7.2	FSPM type C	YES	–
7.3	FSPM type F	NO	–
8	Application relationship protocol machine (ARPM)	–	–
8.1	ARPM type C	YES	–
8.2	ARPM type F	NO	–
9	DLL mapping protocol machine (DMPM)	–	–
9.1	DMPM type C	YES	–
9.2	DMPM type F	NO	–

20.2.4 Performance indicator selection

20.2.4.1 Performance indicator overview

Table 238 provides an overview of the CP 8/4 performance indicators.

Table 238 – CP 8/4: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	YES	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	NO	–
Non-time-based synchronization accuracy	NO	–
Redundancy recovery time	YES	–

20.2.4.2 Performance indicator dependencies

Table 239 specifies the dependencies of the performance indicators (row) from the influencing performance indicators (column).

Table 239 – CP 8/4: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Non-time-based synchronization accuracy	Redundancy recovery time
Delivery time		Yes	No	No	Yes	Yes	No	Yes
Number of end-stations	No		No	No	No	No	No	No
Basic network topology	No	No		No	No	No	No	No
Number of switches between end-stations	No	No	No		No	No	No	No
Throughput RTE	Yes	Yes	No	No		Yes	No	Yes
Non-RTE bandwidth	No	No	No	No	No		No	No
Non-time-based synchronization accuracy	No	No	No	No	No	No		No
Redundancy recovery time	No	No	No	No	No	No	No	

20.2.4.3 Delivery time

20.2.4.3.1 Delivery time calculation

The delivery time between any two end-stations is calculated as the sum of the following:

- sender delay time (see 20.2.4.3.2)
- transmission time (see 20.2.4.3.3)
- receiver delay time (see 20.2.4.3.4)

NOTE Unless otherwise specified, the following units apply: all time units are microseconds, all sizes are octets, and all rates are Mbit/s.

20.2.4.3.2 Sender delay time

20.2.4.3.2.1 Sender delay time calculation

The sender delay time is calculated as the sum of the following:

- send buffer transfer time (see 20.2.4.3.2.2)
- frame transmission time (see 20.2.4.3.2.3)
- transmission delay time (see 20.2.4.3.2.4)

20.2.4.3.2.2 Send buffer transfer time

The send buffer transfer time is calculated as the product of the following:

- cyclic data transfer size
- send buffer transfer time (µs/octet)

The send buffer transfer time is specified by the manufacturer. A typical value is 0,01 µs/octet.

20.2.4.3.2.3 Frame transmission time

The frame transmission time is calculated as the sum of the following:

- cyclic data transfer time
- cyclic data header transfer time
- frame gap time
- preamble time

The cyclic data transfer time is calculated as shown in Formula (97):

$$\textit{cyclic data transfer time} = \textit{cyclic data transfer size} * 8 / \textit{transmission rate} \quad (97)$$

The transmission rate is specified by the manufacturer. A typical value is 1 000 Mbit/s.

The cyclic data header transfer time is calculated as shown in Formula (98):

$$\textit{cyclic data header transfer time} = 44 * \textit{number of cyclic data frames} * 8 / \textit{transmission rate} \quad (98)$$

The number of cyclic data frames is calculated as shown in Formula (99):

$$\textit{number of cyclic data frames} = 1 + (\textit{cyclic data transfer size} / (1518 - 44)) \quad (99)$$

NOTE In Formula (99) the calculated value is truncated to yield an integer result

The frame gap time is calculated as shown in Formula (100):

$$\textit{frame gap time} = 12 * (\textit{number of cyclic data frames} - 1) * 8 / \textit{transmission rate} \quad (100)$$

The preamble time is calculated as shown in Formula (101):

$$\textit{preamble time} = 8 * (\textit{number of cyclic data frames} - 1) * 8 / \textit{transmission rate} \quad (101)$$

20.2.4.3.2.4 Transmission delay time

The transmission delay time is specified by the manufacturer. A typical value is 0,35 µs.

20.2.4.3.3 Transmission time

20.2.4.3.3.1 Transmission time calculation

The transmission time is calculated as the sum of the following:

- repeaters delay time (see 20.2.4.3.3.2)
- transmission channel delay time (see 20.2.4.3.3.3)

20.2.4.3.3.2 Repeaters delay time

The repeater delay time is calculated as shown in Formula (102):

$$\textit{repeater delay time} = \textit{repeater delay time} * (\textit{number of stations} - 2) \quad (102)$$

The repeater delay time is specified by the manufacturer. A typical value is 0,7 µs.

20.2.4.3.3.3 Transmission channel delay time

The transmission channel delay time is calculated as shown in Formula (103):

transmission channel delay time = transmission channel length (Km) / 210 000 (Km/s) (103)

20.2.4.3.4 Receiver delay time

20.2.4.3.4.1 Receiver delay time calculation

The receiver delay time is calculated as shown in Formula (104):

receiver delay time = receive delay time + receive buffer transfer time (104)

See 20.2.4.3.4.2 for receive delay time and 20.2.4.3.4.3 for receive buffer transfer time.

20.2.4.3.4.2 Receive delay time

The receive delay time is specified by the manufacturer. A typical value is 0,35 μs.

20.2.4.3.4.3 Receive buffer transfer time

The receive buffer transfer time is calculated as shown in Formula (105):

*receive buffer transfer time = cyclic data transfer size * receive buffer transfer time (μs/octet)* (105)

The receive buffer transfer time is specified by the manufacturer. A typical value is 0,01 μs/octet.

20.2.4.4 Number of end-stations

The maximum number of end-stations is 256. This value is not influenced by any other PI.

20.2.4.5 Basic network topology

The basic network topology, a ring, is fixed.

20.2.4.6 Number of switches between end-stations

No switches are used.

20.2.4.7 Throughput RTE

The Throughput RTE is calculated as shown in Formula (106):

*throughput RTE = cyclic data transfer size * 8 / token circulation time* (106)

The token circulation time is calculated as shown in Formula (107):

*token circulation time = (sender delay time + transmission channel delay time + receiver delay time + token frame time) * number of stations* (107)

The token frame time is calculated as shown in Formula (108):

*token frame time = 64 * 8 / transmission rate* (108)

20.2.4.8 Non-RTE bandwidth

The non-RTE bandwidth is influenced by the throughput RTE. The relationship shown in Formula (109) expressed as a ratio of two rates (all terms are Mbit/s), describes this dependency:

non-RTE bandwidth < (transmission rate – throughput RTE – protocol overhead) / transmission rate (109)

The protocol overhead is calculated as the sum of the following:

- cyclic data overhead
- acyclic data overhead

The cyclic data overhead is calculated as shown in Formula (110):

*cyclic data overhead = (44 * 8 / token circulation time) * number of cyclic data frames* (110)

The acyclic data overhead is calculated as shown in Formula (111):

*acyclic data overhead = (44 * 8 / token circulation time) * number of acyclic data frames* (111)

The number of acyclic data frames is calculated as in Formula (112):

number of acyclic data frames = 1 + (acyclic data transfer size / (1518 – 48)) (112)

NOTE The value of number of acyclic data frames calculated with Formula (112) is truncated to yield an integer result.

20.2.4.9 Time synchronization accuracy

Void.

20.2.4.10 Non-time-based synchronization accuracy

Void.

20.2.4.11 Redundancy recovery time

The redundancy recovery time is not dependent on any other PI. The redundancy recovery time influences delivery time and throughput RTE. The influence on delivery time is not parametric because the transmission protocol does not include the retransmission procedure, however, a redundancy recovery event has a direct correlation on throughput RTE as influenced by the change in transmission pass.

20.2.4.12 Consistent set of performance indicators for large automation systems

Table 240 gives an outline of a consistent set of performance indicators for a large automation system.

Table 240 – CP 8/4: Consistent set of PIs (real-time only)

Performance indicator	Value	Constraints
Delivery time	200 µs	No failure
Number of end-stations	120	Ring topology
Number of switches between end-stations	NA	–
Throughput RTE	50 Moctets/s	–
Non-RTE bandwidth	0	In this scenario, non-RTE traffic is not configured although possible
Redundancy recovery time	< 100 ms	–

Table 241 gives an outline of a consistent set of performance indicators for a large automation system. The slot for no-real-time data is 240 000 octets per cycle time.

Table 241 – CP 8/4: Consistent set of PIs (real-time and non-real-time)

Performance indicator	Value	Constraints
Delivery time	217 µs	No failure
Number of end-stations	120	Ring topology
Number of switches between end-stations	NA	–
Throughput RTE	35 Moctets/s	–
Non-RTE bandwidth	48,4 %	In this scenario, The slot for no-real-time data is 240 000 octets per cycle time.
Redundancy recovery time	< 100 ms	–

20.3 Profile 8/5

20.3.1 Physical layer

The physical layer of CP 8/5 is as specified in ISO/IEC 8802-3.

20.3.2 Data link layer

The data link layer of CP 8/5 is as specified in ISO/IEC 8802-3.

20.3.3 Application layer

20.3.3.1 AL service selection

Application Layer services are defined in IEC 61158-5-23. Table 242 shows the subclauses included in this profile.

Table 242 – CP 8/5: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviated terms and conventions	YES	–
4	Concept	YES	–
5	Data type ASE	YES	–
6	Communication model specification	–	–
6.1	Communication model	YES	–
6.2	ASE	–	–
6.2.1	Overview type C	NO	–
6.2.2	Overview type F	YES	–
6.2.3	Cyclic data ASE type C	NO	–
6.2.4	Cyclic data ASE type F	YES	–
6.2.5	Acyclic data ASE type C	NO	–
6.2.6	Acyclic data ASE type F	YES	–
6.2.7	Management ASE	YES	–
6.2.8	Synchronization ASE	YES	–
6.2.9	Measurement ASE	YES	–
6.3	AR Type C	NO	–
6.4	AR Type F	YES	–

20.3.3.2 AL protocol selection

Application Layer protocols are defined in IEC 61158-6-23. Table 243 shows the subclauses included in this profile.

Table 243 – CP 8/5: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviated terms and conventions	YES	–
4	FAL syntax description	–	–
4.1	FALPDU type C abstract syntax	NO	–
4.2	FALPDU type F abstract syntax	YES	–
4.3	Data assignmentds for type C	NO	–
4.4	Data assignmentds for type F	YES	–
5	FAL transfer syntax	–	–
5.1	Encoding rules	YES	–
5.2	FALPDU type C elements encoding	NO	–
5.3	FALPDU type F elements encoding	YES	–
6	Structure of the FAL protocol state machine	YES	–
7	FAL service protocol machine (FSPM)	–	–
7.1	Overview	YES	–
7.2	FSPM type C	NO	–
7.3	FSPM type F	YES	–
8	Application relationship protocol machine (ARPM)	–	–
8.1	ARPM type C	NO	–
8.2	ARPM type F	YES	–
9	DLL mapping protocol machine (DMPM)	–	–
9.1	DMPM type C	NO	–
9.2	DMPM type F	YES	–

20.3.4 Performance indicator selection

20.3.4.1 Performance indicator overview

Table 244 provides an overview of the CP 8/5 performance indicators.

Table 244 – CP 8/5: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	YES	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	NO	–
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	YES	–

20.3.4.2 Performance indicator dependencies

Table 245 specifies the dependencies of the performance indicators (row) from the influencing performance indicators (column).

Table 245 – CP 8/5: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Non-time-based synchronization accuracy	Redundancy recovery time
Delivery time		Yes	Yes	Yes	Yes	Yes	No	Yes
Number of end-stations	No		No	No	No	No	No	No
Basic network topology	No	No		No	No	No	No	No
Number of switches between end-stations	Yes	No	Yes		Yes	No	No	No
Throughput RTE	Yes	Yes	No	Yes		No	No	Yes
Non-RTE bandwidth	No	No	No	No	Yes		No	No
Non-time-based synchronization accuracy	Yes	Yes	Yes	Yes	No	No		Yes
Redundancy recovery time	Yes	Yes	Yes	Yes	No	No	No	

20.3.4.3 Delivery time

20.3.4.3.1 Delivery time calculation

The delivery time between any two end-stations is calculated as the sum of the following:

- sender delay time (see 20.3.4.3.2)
- transmission time (see 20.3.4.3.3)
- receiver delay time (see 20.3.4.3.4)

NOTE Unless otherwise specified, the following units apply: all time units are microseconds, all sizes are octets, and all rates are Mbit/s.

20.3.4.3.2 Sender delay time

20.3.4.3.2.1 Sender delay time calculation

The sender delay time is calculated as the sum of the following:

- send buffer transfer time (see 20.3.4.3.2.2)
- frame transmission time (see 20.3.4.3.2.3)
- transmission delay time (see 20.3.4.3.2.4)

20.3.4.3.2.2 Send buffer transfer time

The send buffer transfer time is calculated as the product of the following:

- cyclic data transfer size
- send buffer transfer time (µs/octet)

The send buffer transfer time is specified by the manufacturer. A typical value is 0,05 µs/octet.

20.3.4.3.2.3 Frame transmission time

The frame transmission time is calculated as the sum of the following:

- cyclic data transfer time
- cyclic data header transfer time
- frame gap time
- preamble time
- token frame time
- my status frame time

The cyclic data transfer time is calculated as shown in Formula (113):

*cyclic data transfer time = cyclic data transfer size * 8 / transmission rate* (113)

The transmission rate is specified by the manufacturer. A typical value is 1 000 Mbit/s.

The cyclic data header transfer time is calculated as shown in Formula (114):

*cyclic data header transfer time = 40 * number of cyclic data frames * 8 / transmission rate* (114)

The number of cyclic data frames is calculated as shown in Formula (115):

number of cyclic data frames = 1 + (cyclic data transfer size / (1518 – 40)) (115)

NOTE In Formula (115) the calculated value is truncated to yield an integer result

The frame gap time is calculated as shown in Formula (116):

*frame gap time = 12 * (number of cyclic data frames + 1) * 8 / transmission rate* (116)

The preamble time is calculated as shown in Formula (117):

*preamble time = 8 * (number of cyclic data frames + 2) * 8 / transmission rate* (117)

The token frame time is calculated as shown in Formula (118):

*token frame time = 64 * 8 / transmission rate* (118)

The my status frame time is calculated as shown in Formula (119):

*my status frame time = 64 * 8 / transmission rate* (119)

20.3.4.3.2.4 Transmission delay time

The transmission delay time is specified by the manufacturer. A typical value is 0,165 μs.

20.3.4.3.3 Transmission time

20.3.4.3.3.1 Transmission time calculation

The transmission time is calculated as the sum of the following:

- repeaters delay time (see 20.3.4.3.3.2)
- transmission channel delay time (see 20.3.4.3.3.3)
- switches delay time (see 20.3.4.3.3.4)

20.3.4.3.3.2 Repeaters delay time

The repeaters delay time is calculated as shown in Formula (120):

*repeaters delay time = repeater delay time * (number of stations – 2)* (120)

The repeaters delay time is specified by the manufacturer. A typical value is 0,99 µs.

20.3.4.3.3.3 Transmission channel delay time

The transmission channel delay time is calculated as shown in Formula (121):

transmission channel delay time = transmission channel length (Km) / 210 000 (Km/s) (121)

20.3.4.3.3.4 Switches delay time

The switches delay time is calculated as shown in Formula (122):

*switches delay time = switch delay time * number of switches between end-stations* (122)

The switches delay time is specified by the manufacturer. A typical value is 8,0 µs.

20.3.4.3.4 Receiver delay time

20.3.4.3.4.1 Receiver delay time calculation

The receiver delay time is calculated as the sum of the following:

- receive delay time (see 20.3.4.3.4.2)
- frame receive time (see 20.3.4.3.4.3)
- receive buffer transfer time (see 20.3.4.3.4.4)

20.3.4.3.4.2 Receive delay time

The receive delay time is specified by the manufacturer. A typical value is 0,165 µs.

20.3.4.3.4.3 Frame receive time

The frame receive time is equal to the frame transmission time.

20.3.4.3.4.4 Receive buffer transfer time

The receive buffer transfer time is calculated as shown in Formula (123):

*receive buffer transfer time = cyclic data transfer size * receive buffer transfer time (µs/octet)* (123)

The receive buffer transfer time is specified by the manufacturer. A typical value is 0,05 µs/octet.

20.3.4.4 Number of end-stations

The maximum number of end-stations is 121. This value is not influenced by any other PI.

20.3.4.5 Basic network topology

The basic network topology is designed in linear, star or ring according to the delvery time application.

20.3.4.6 Number of switches between end-stations

The number of switches between end-stations shall be optimized to a minimum value in order that delivery time meets applcation constraints.

20.3.4.7 Throughput RTE

The Throughput RTE is calculated as shown in Formula (124):

*throughput RTE = cyclic data transfer size * 8 / link scan time* (124)

The link scan time is specified by the manufacturer.

20.3.4.8 Non-RTE bandwidth

The non-RTE bandwidth is influenced by the throughput RTE. The relationship in Formula (125) expressed as a ratio of two rates (all terms are Mbit/s), describes this dependency:

non-RTE bandwidth < (transmission rate – throughput RTE – acyclic data overhead) / transmission rate (125)

The acyclic data overhead is calculated as shown in Formula (126):

*acyclic data overhead = (44 * 8 / link scan time) * number of acyclic data frames* (126)

The number of acyclic data frames is calculated as shown in Formula (127):

number of acyclic data frames = 1 + (acyclic data transfer size / (1518 – 44)) (127)

NOTE In Formula (127) the calculated value is truncated to yield an integer result.

20.3.4.9 Time synchronization accuracy

Void.

20.3.4.10 Non-time-based synchronization accuracy

The synchronization accuracy is dependent on the delivery time, the number of end-stations, the basic network topology, the number of switches between end-stations and the redundancy recovery time.

20.3.4.11 Redundancy recovery time

The redundancy recovery time is dependent on the delivery time, the number of end-stations, the basic network topology and the number of switches between end-stations. The redundancy recovery time influences delivery time, non-time-base synchronization accuracy and throughput RTE. The influence on delivery time is not parametric because the transmission protocol does not include the retransmission procedure, however, a redundancy recovery event has a direct correlation on throughput RTE *and non-time-base synchronization accuracy* as influenced by the change in transmission pass.

20.3.4.12 Consistent set of performance indicators for large automation systems

Table 246 gives an outline of a consistent set of performance indicators for a large automation system.

Table 246 – CP 8/5: Consistent set of PIs (real-time only)

Performance indicator	Value	Constraints
Delivery time	118 µs	No failure
Number of end-stations	120	Linear topology
Number of switches between end-stations	0	–
Throughput RTE	72 Moctets/s	–
Non-RTE bandwidth	0	In this scenario, non-RTE traffic is not configured although possible
Non-time-based synchronization accuracy	< 1 µs	–
Redundancy recovery time	< 8 ms	–

Table 247 gives an outline of a consistent set of performance indicators for a large automation system. The slot for no-real-time data is 8 Koctets per cycle time.

Table 247 – CP 8/5: Consistent set of PIs (real-time and non-real-time)

Performance indicator	Value	Constraints
Delivery time	225 µs	No failure
Number of end-stations	120	Linear topology
Number of switches between end-stations	0	–
Throughput RTE	12 Moctets/s	–
Non-RTE bandwidth	20 %	In this scenario, The slot for no-real-time data is 8 Koctets per cycle time.
Non-time-based synchronization accuracy	< 1 µs	–
Redundancy recovery time	< 8 ms	–

Annex A
(informative)

Performance Indicator calculation

A.1 CPF 2 (CIP) – Performance indicator calculation

A.1.1 Profile 2/2 EtherNet/IP

A.1.1.1 Delivery time

Using the formulae specified in 7.2.4.2.2, minimum and maximum values of delivery time can be calculated based on the following assumptions:

- $SD_s = SD_r = 50$ µs;
- APDU size = 32 octets;
- CP 2/2 protocol overhead (PO) = 84 octets;
- Link data rate (LDR) = 100 Mbit/s;
- All cable segments are of the same length and of the same cable type;
- Cable propagation delay (PD) = 5 ns/m;
- Cable length (CL) = 100 m;
- Switch processing delay (SPD) = 10 µs;
- Minimum number of switches (n_{min}) = 1;
- Maximum number of switches (n_{max}) = 1 024;
- No RTE packets in the transmit queue in front of this packet;
- No transmission errors.

$$T_{x\_packet} = \frac{(APDUsize + PO) \times 8}{LDR} = \frac{(32 + 84) \times 8}{1 \times 10^5} = 9{,}3\,\mu s$$

$$CD_i = PD_i \times CL_i = 500\,ns = 0{,}5\,\mu s$$

$$SL_k = SPD_k + T_{x\_packet} = 19{,}3\,\mu s$$

$$DT_{\min} = 50 + 9{,}3 + 2 \times 0{,}5 + 19{,}3 + 50 = 129{,}6\,\mu s \approx 130\,\mu s$$

$$DT_{\max} = 50 + 9{,}3 + 1024 \times 0{,}5 + 1\,024 \times 19{,}3 + 50 = 20\,384{,}5\,\mu s \approx 20{,}4\,ms$$

A.1.1.2 Throughput RTE

The maximum theoretical throughput RTE is calculated based on the following assumptions:

- all APDUs are of the same size;
- APDU size = 32 octets;
- CP 2/2 protocol overhead (PO) = 84 octets;
- Link data rate (LDR) = 100 Mbit/s.

$$T_{x\_packet} = \frac{(APDUsize + PO) \times 8}{LDR} = \frac{(32 + 84) \times 8}{1 \times 10^5} = 9{,}3\,\mu s$$

$$EN\_PR\_MAX = \frac{1}{T_{x\_packet}} = \frac{1}{9{,}3 \times 10^{-6}} \approx 107\,500\,pps$$

$$Throughput\_RTE_{max\_theoretical} = 32 \times 107\,500 = 3{,}44 \times 10^{6}\ octets/s$$

A.1.2 Profile 2/2.1 EtherNet/IP with Time Synchronization

A.1.2.1 Delivery time

Using the formulae specified in 7.2.4.2.2, minimum and maximum values of delivery time can be calculated based on the following assumptions:

- $SD_s = SD_r = 50\ \mu s$;
- APDU size = 32 octets;
- CP 2/2 protocol overhead (PO) = 84 octets;
- Link data rate (LDR) = 100 Mbit/s;
- All cable segments of the same length and of the same cable type;
- Cable propagation delay (PD) = 5 ns/m;
- Cable length (CL) = 100 m;
- Switch processing delay (SPD) = 10 μs;
- Minimum number of switches (n_{min}) = 1;
- Maximum number of switches (n_{max}) = 4;
- No RTE packets in the transmit queue in front of this packet;
- No transmission errors.

$$T_{x\_packet} = \frac{(APDUsize + PO) \times 8}{LDR} = \frac{(32 + 84) \times 8}{1 \times 10^{5}} = 9{,}3\,\mu s$$

$$CD_i = PD_i \times CL_i = 500\,ns = 0{,}5\,\mu s$$

$$SL_k = SPD_k + T_{x\_packet} = 19{,}3\,\mu s$$

$$DT_{min} = 50 + 9{,}3 + 2 \times 0{,}5 + 19{,}3 + 50 = 129{,}6\,\mu s \approx 130\,\mu s$$

$$DT_{max} = 50 + 9{,}3 + 4 \times 0{,}5 + 4 \times 19{,}3 + 50 = 188{,}5\,\mu s \approx 190\,\mu s$$

A.1.2.2 Maximum number of end-stations

Presently, the maximum number of ports in a switch with boundary clock is 24. The maximum number of nodes in a 2-layer star network with 4 switches, N_{max}, is:

$$N_{max} = (24 - 3) + [3 \times (24 - 1)] = 90$$

A.2 CPF 3 – PROFINET – Performance indicator calculation

A.2.1 Application Scenario

The application scenario for the consistent set of performance indicators has been selected for a typical configuration for factory automation. In general, the number of nodes is only limited by the delivery time.

A.2.2 Structural examples used for calculation

A.2.2.1 CP 3/4

A.2.2.1.1 Line structure

To reduce the amount of cabling a line structure is selected. In Figure A.1 the structure is shown for 60 nodes.

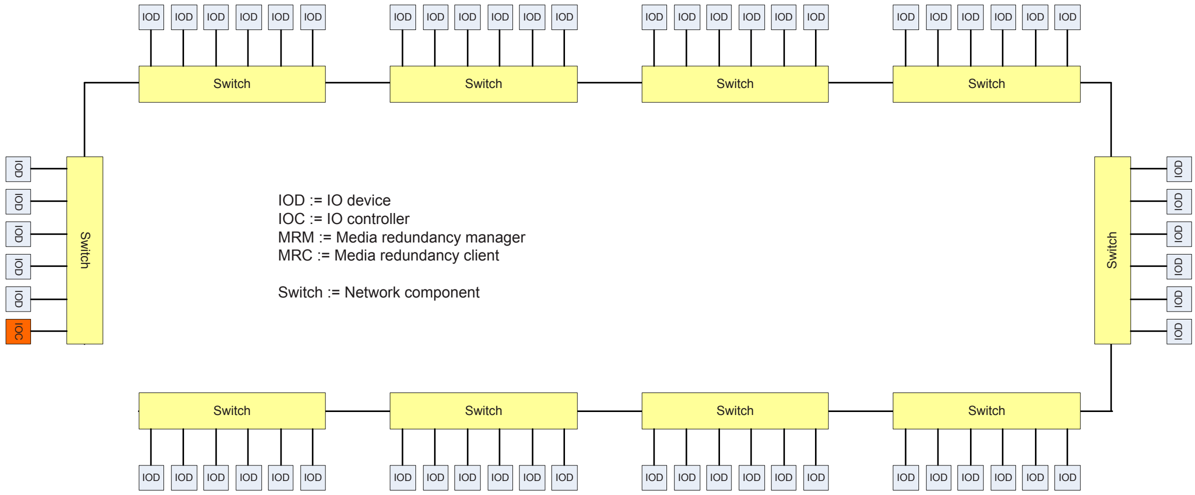

Figure A.1 – CP 3/4: Example of line structure

A.2.2.1.2 Ring structure

To reduce the amount of cabling a line structure is selected. To increase the availability, a ring structure for media redundancy is shown in Figure A.2 for 60 nodes. In this case media redundancy is a feature of the switches.

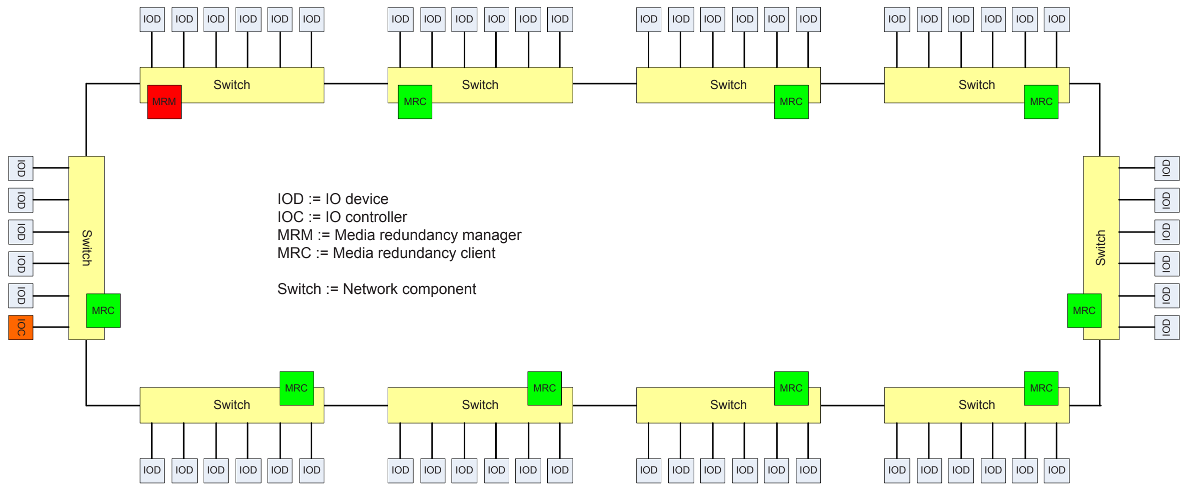

Figure A.2 – CP 3/4: Example of ring structure

A.2.2.1.3 Tree or star structure

Tree or star structure offers the possibility to switch off bigger parts of a machine. They need more cabling.

A.2.2.1.4 Wireless structure

A.2.2.1.4.1 Wireless bridge

An example of a wireless topology is shown in Figure A.3. The wireless bridge (2 access points or 1 access point and 1 client) are used to connect two wired network segments.

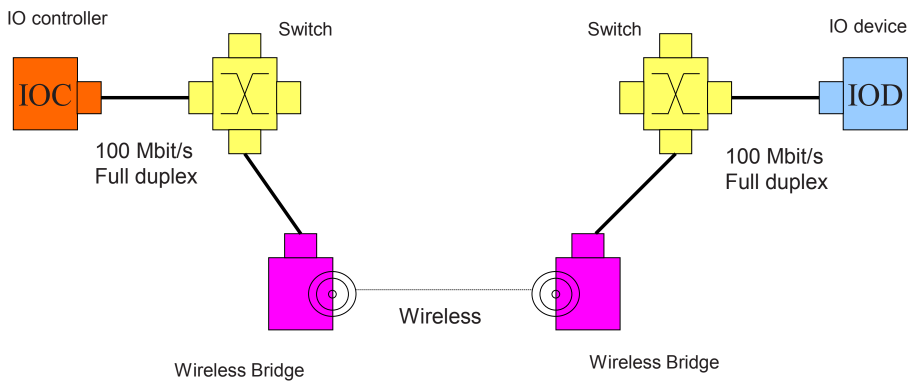

Figure A.3 – CP 3/4: Example of a wireless segment

A.2.2.1.4.2 Wireless Client

An example of a wireless topology is shown in Figure A.4. The IO device uses its integrated wireless client to connect via the wireless access points to the IO controller.

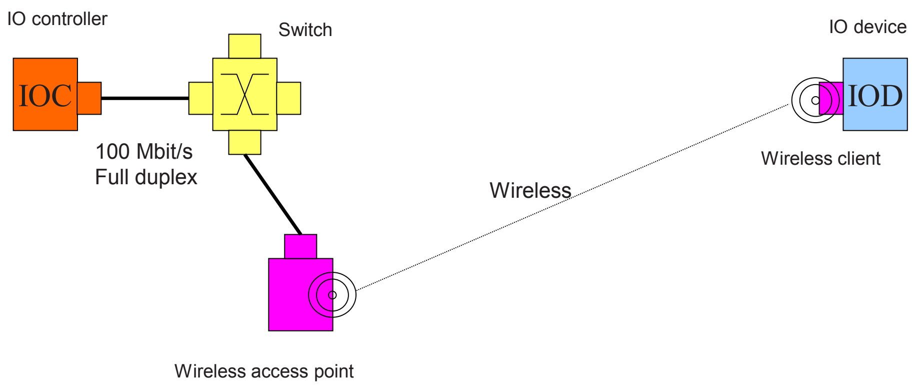

Figure A.4 – CP 3/4: Example of an integrated wireless client

A.2.2.2 CP 3/5

A.2.2.2.1 Line structure

To reduce the amount of cabling a line structure is selected. In Figure A.5 the structure is shown for 60 nodes.

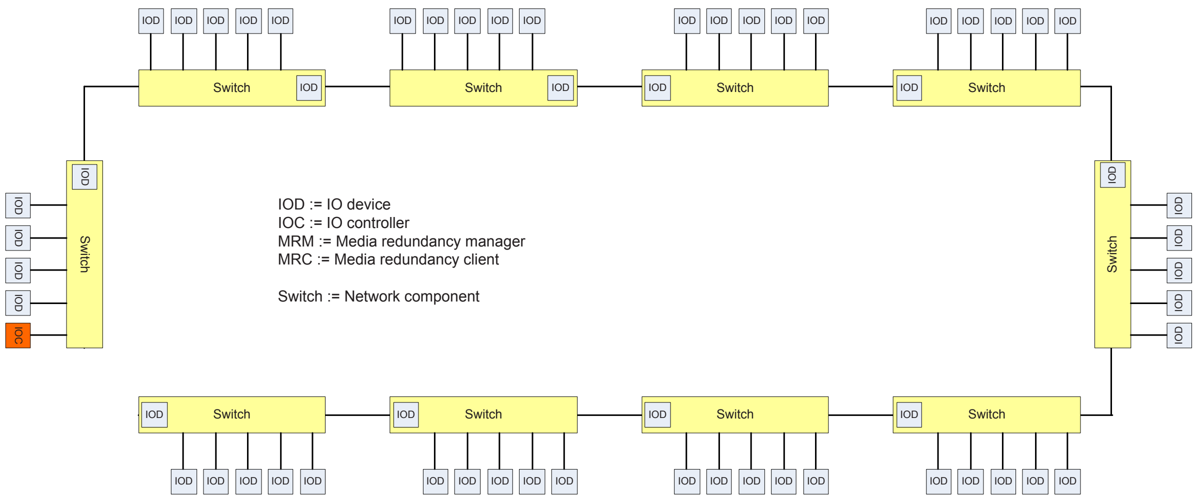

Figure A.5 – CP 3/5: Example of line structure

A.2.2.2.2 Ring structure

To reduce the amount of cabling a line structure is selected. To increase the availability, a ring structure for media redundancy is shown in Figure A.6 for 60 nodes. The ring structure depicted in Figure A.6 offers the ability to use bumpless media redundancy.

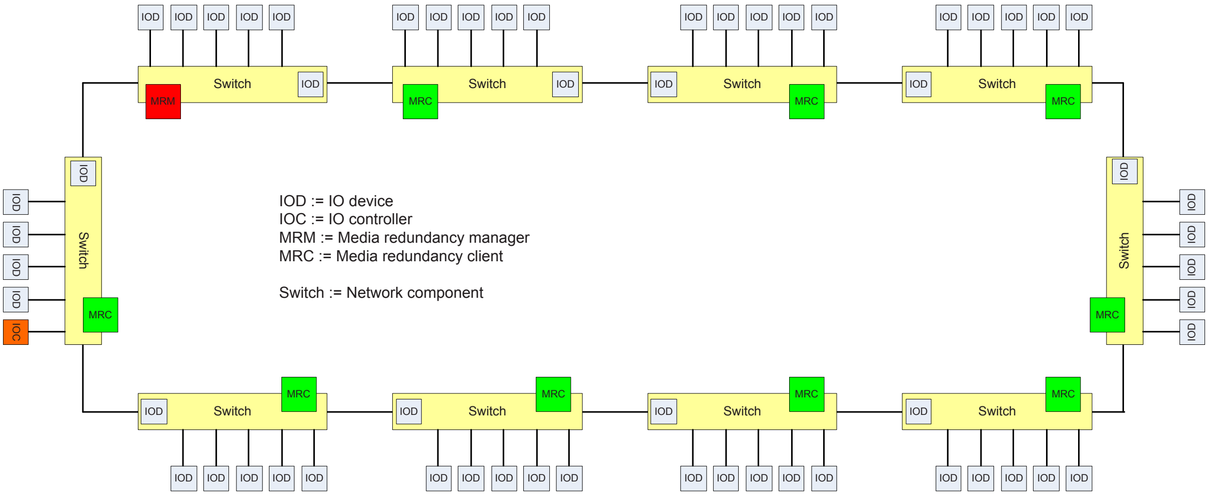

Figure A.6 – CP 3/5: Example of ring structure

A.2.2.2.3 Tree or star structure

See A.2.2.1.3.

A.2.2.3 CP 3/6

A.2.2.3.1 Line structure

To reduce the amount of cabling a line structure is selected. In Figure A.7 the structure is shown for 60 nodes.

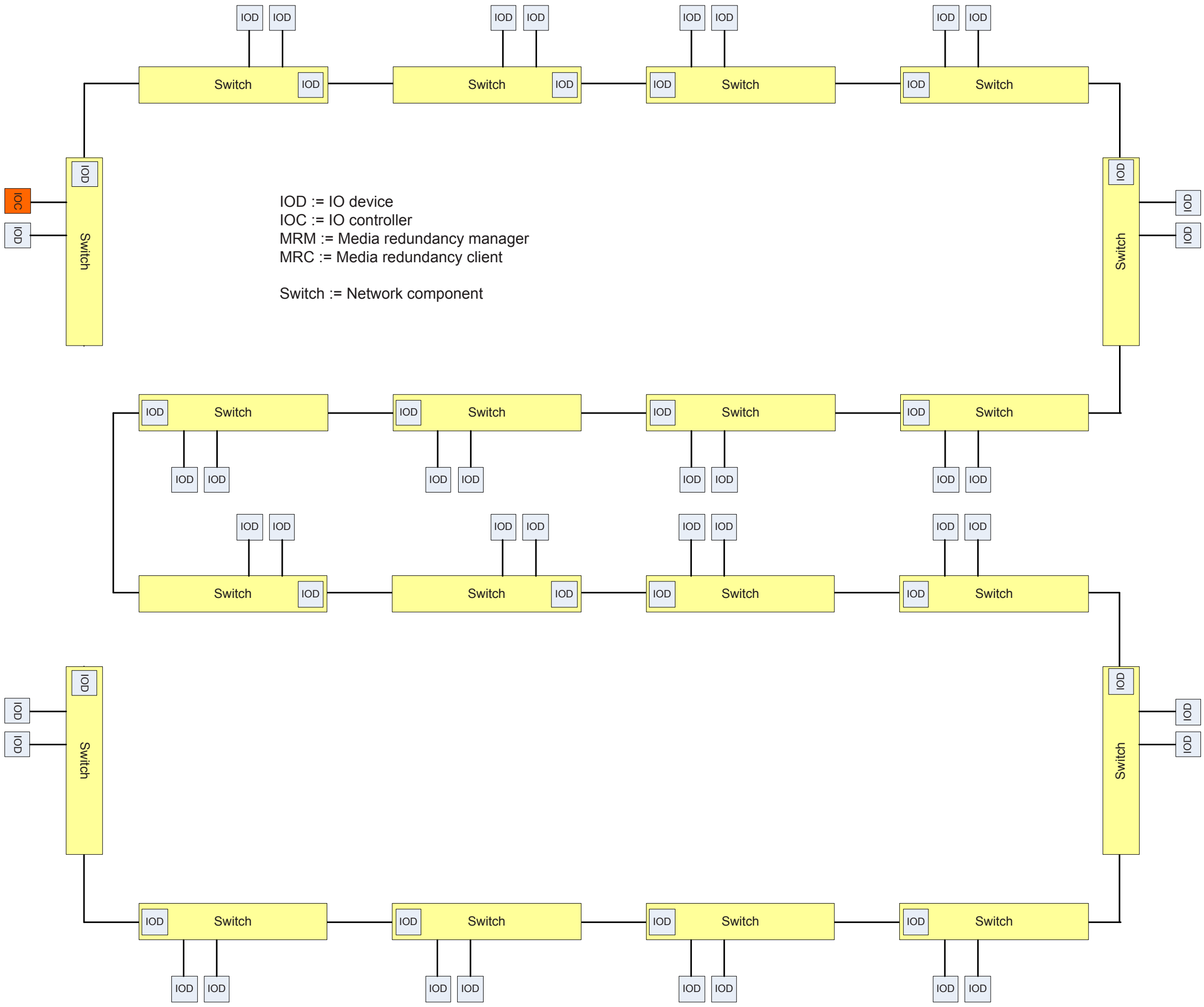

Figure A.7 – CP 3/6: Example of line structure

Figure A.8 shows a line structure with 64 nodes.

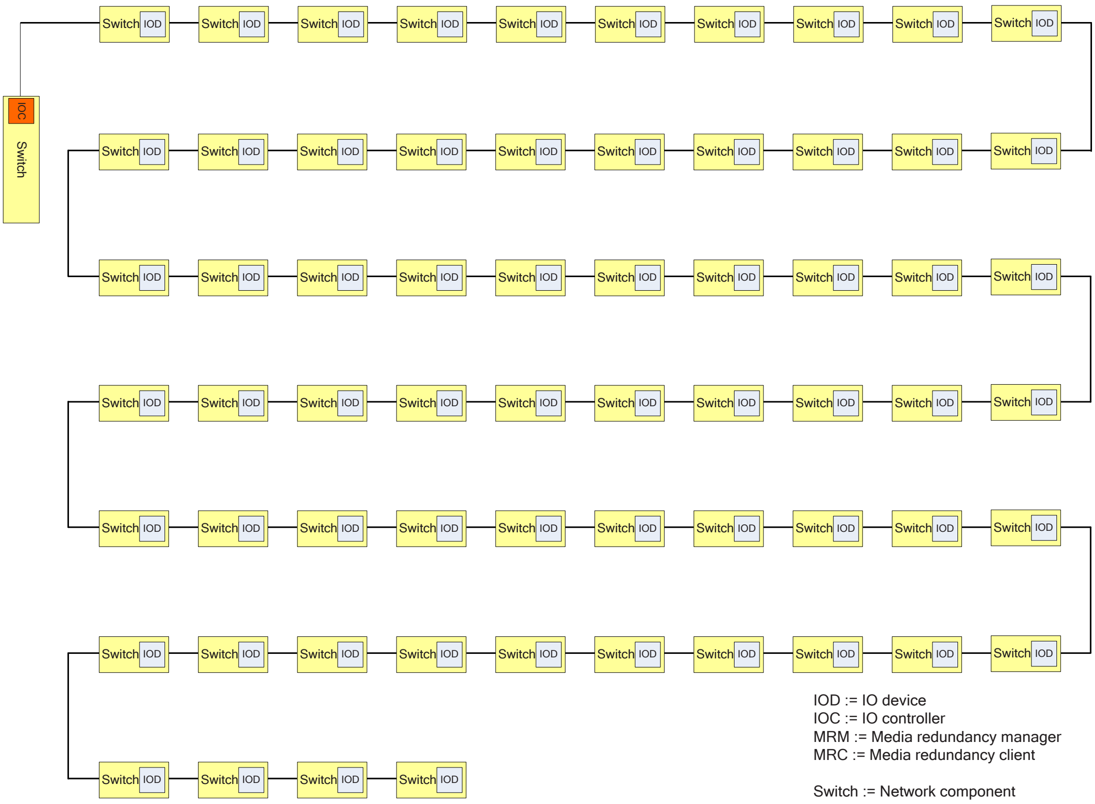

Figure A.8 – CP 3/6: Example of line structure

A.2.2.3.2 Ring structure

To reduce the amount of cabling a line structure is selected. To increase the availability, a ring structure for media redundancy is shown in Figure A.9 for 60 nodes. The structure depicted in Figure A.9 shows the ability to use bumpless media redundancy.

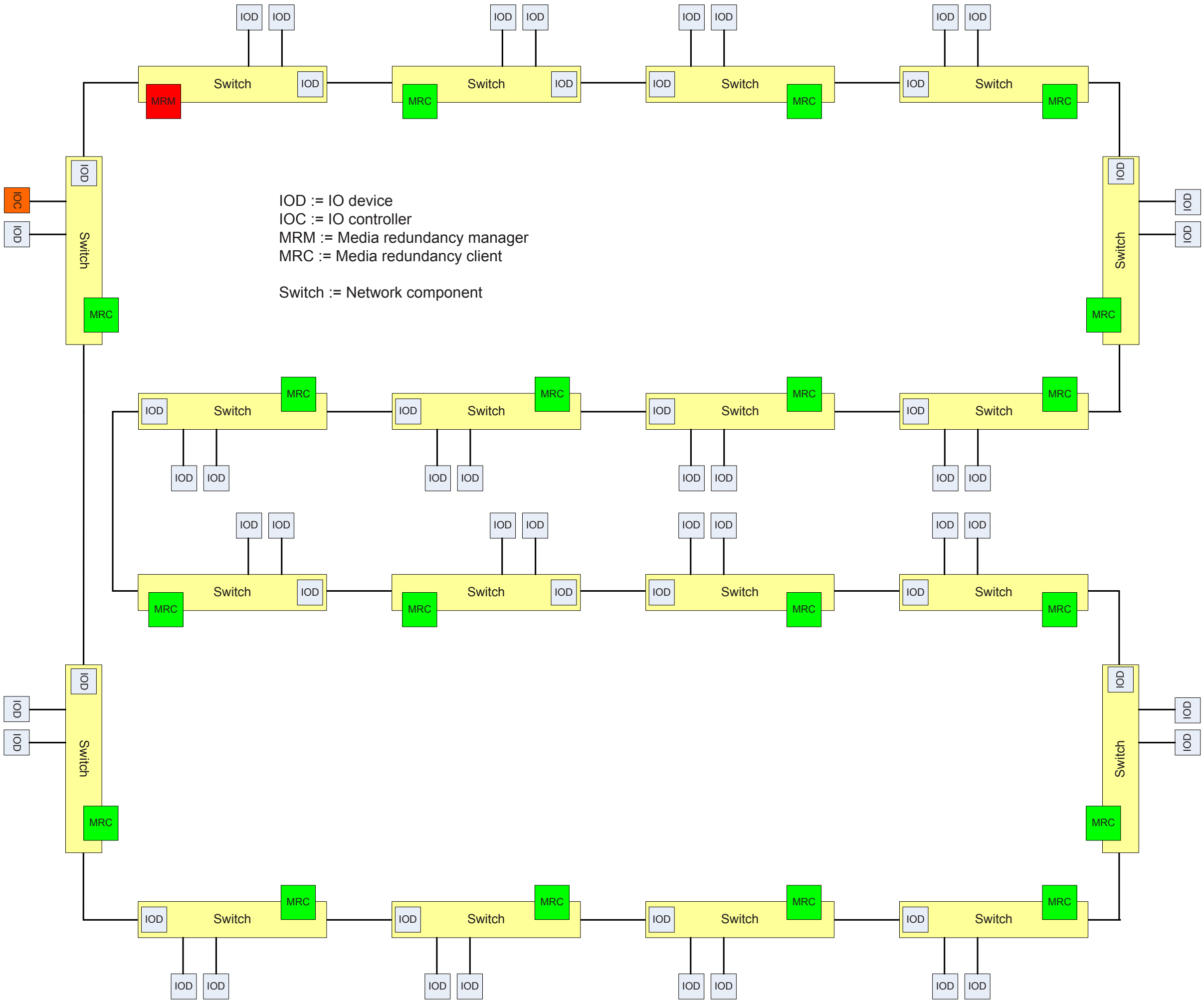

Figure A.9 – CP 3/6: Example of ring structure

A.2.2.3.3 Tree or star structure

Tree or star structure offers the possibility to switch off bigger parts of a machine. They need more cabling. Figure A.10 shows this structure with integrated network components for 60 nodes. This structure offers the possibility to use higher bandwidth to communicate between IO controller and IO device. Each branch (shown as GREEN areas in Figure A.10) may use the full bandwidth of the connected port of the IO controller. It may also be disabled without bothering the other branches.

Figure A.11 shows a comb structure with 64 nodes. Figure A.12 shows a comb structure with more than 64 nodes.

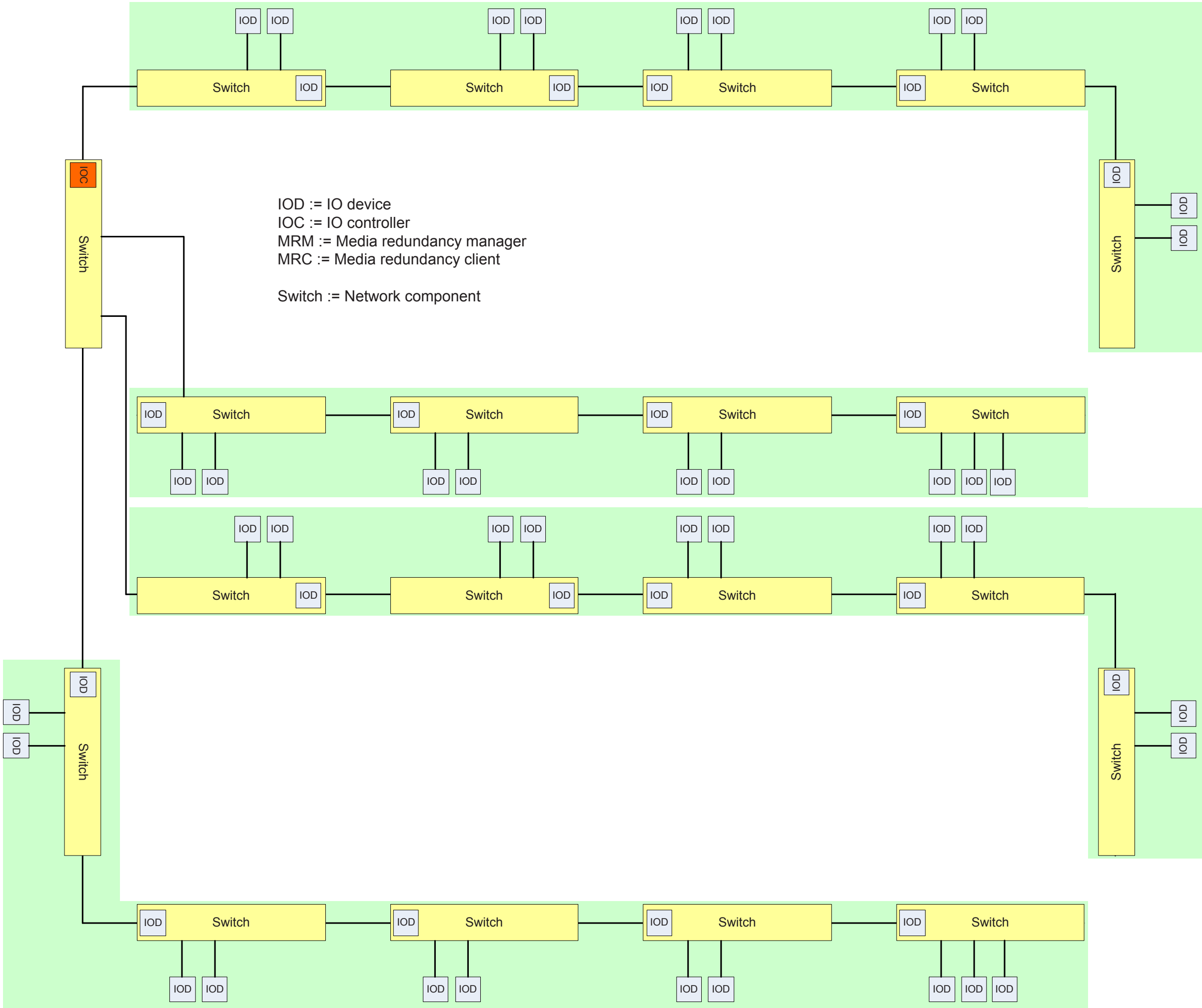

Figure A.10 – CP 3/6: Example of tree structure

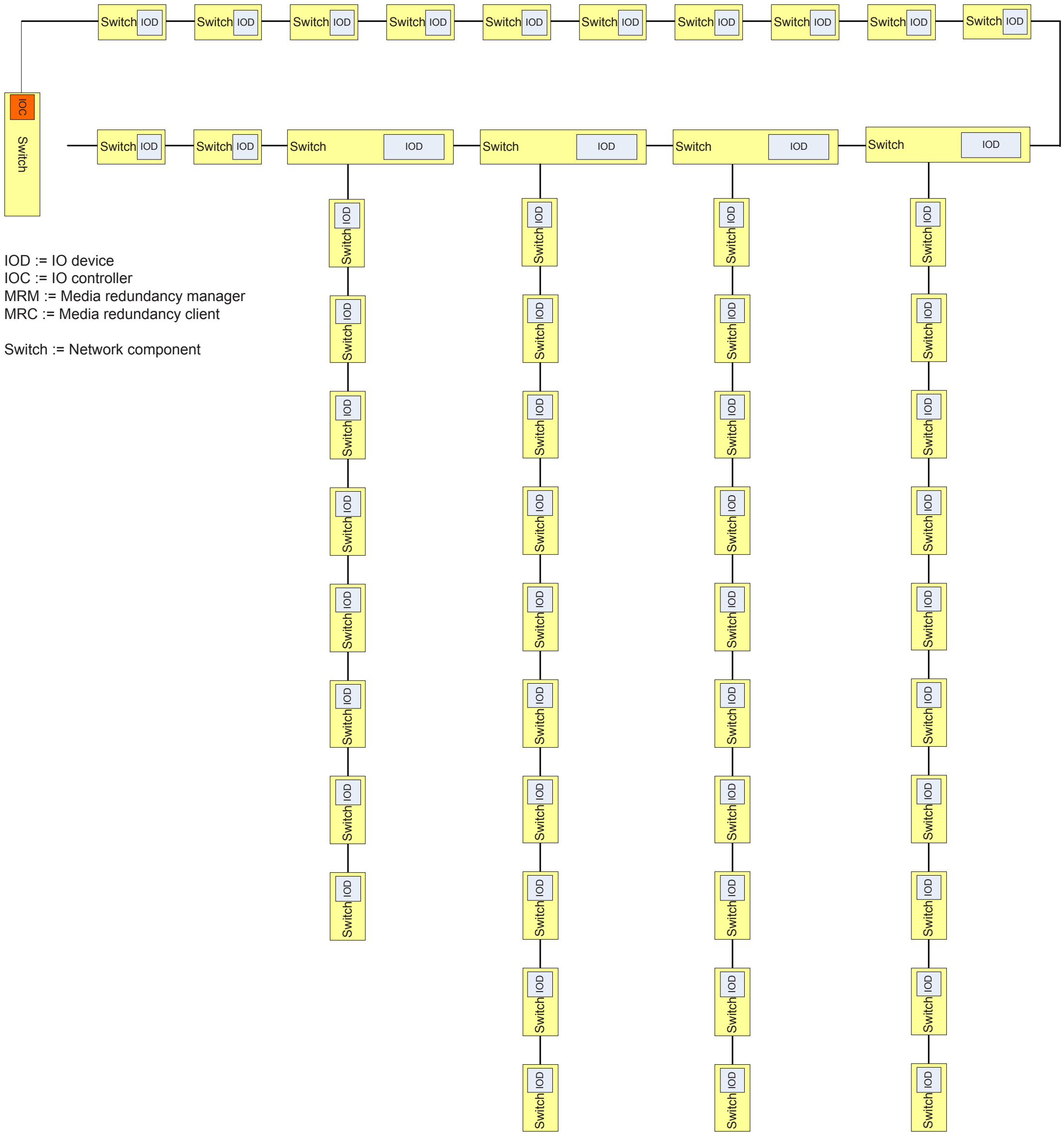

Figure A.11 – CP 3/6: Example of comb structure

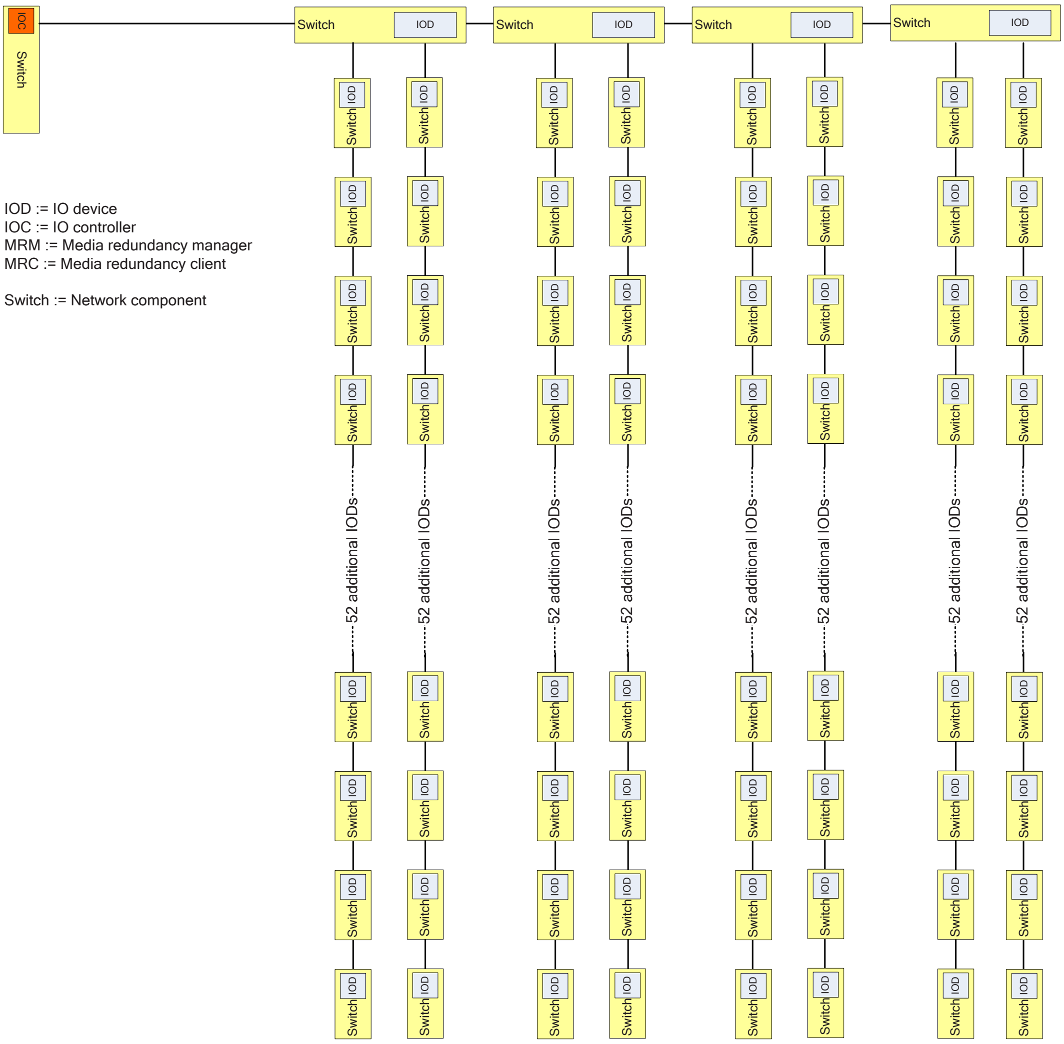

Figure A.12 – CP 3/6: Example of comb structure (optional)

A.2.3 Principles used for calculation

A.2.3.1 General

For Ethernet a switch is the backbone of the communication infrastructure. Its abilities and the stack traversal time are the key figures for the calculation of delivery time.

A.2.3.2 Stack traversal time

The stack traversal time (STT) may be reduced by means of hardware to a memory access.

A.2.3.3 Switch structure

A.2.3.3.1 General

The abilities of a switch, especial the bridging delay (bd) and the amount of frame buffer memory, may be considered further.

A.2.3.3.2 Bridging delay

The bridging delay is specified as the amount of time to transmit a frame from one port to another according to Figure A.13.

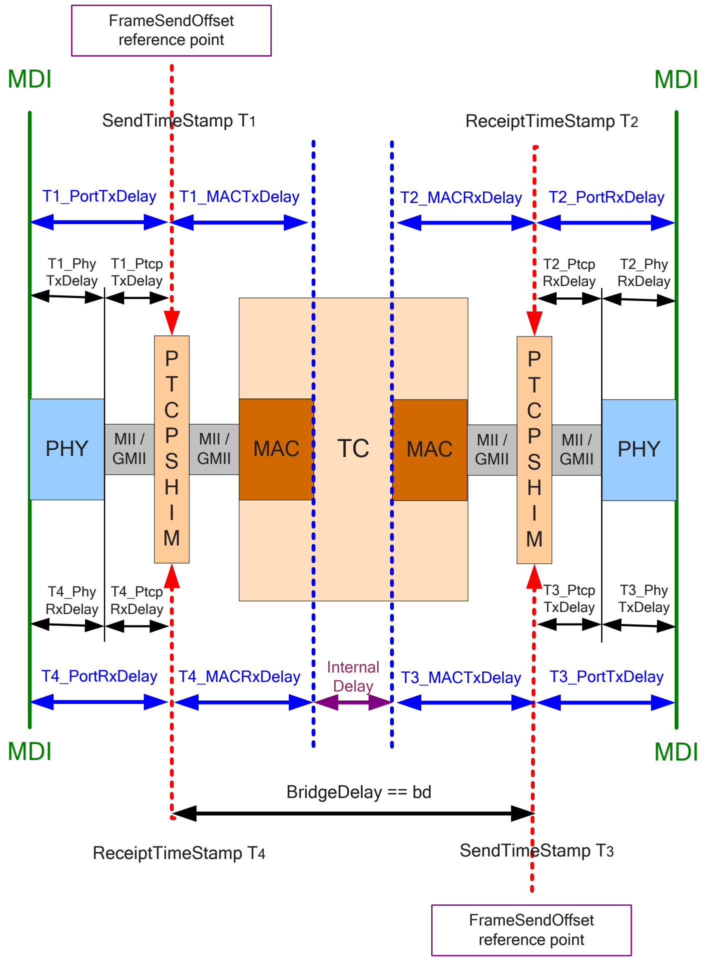

Figure A.13 – Definition of bridge delay

There are at least two different ways to switch a frame. Store and forward (S&F) offers a limited speed, because the whole frame is received over one port, before it can be transmitted over another. Cut through (CT) offers the best available speed, because only a small portion of the frame is received, before it is transmitted over another.

S&F
For 100 Mbit/s a maximum frame takes approx. 125 µs to transmit. This means, the propagation delay of a line is depending to the count of switches multiplied with the frame size.

CT
After receiving up to 64 octets, the transmission over another port is started. This means, the propagation delay of a line is depending to the count of switches, but not multiplied with the frame size.

Internal delay
The calculation of the destination port within the filtering data base and the forwarding of the data stream take time.

A.2.3.3.3 PHY delay

The PHY receive and transmit delay is specified as the amount of time to transmit data according to Figure A.13.

NOTE These delays seem to be marginal. But the value is multiplied by the 'Number of switches between RTE end stations'.

A.2.3.3.4 Frame queues

The switching fabric is designed to handle data streams. These streams are steered by the filtering data base. In a theoretical approach, there are always enough resources to buffer frames in case of traffic jam. In real networks the traffic depends on the structure and the connected end nodes. Figure A.14 shows in principle the structure of a switch integrated into an IO device or an IO controller.

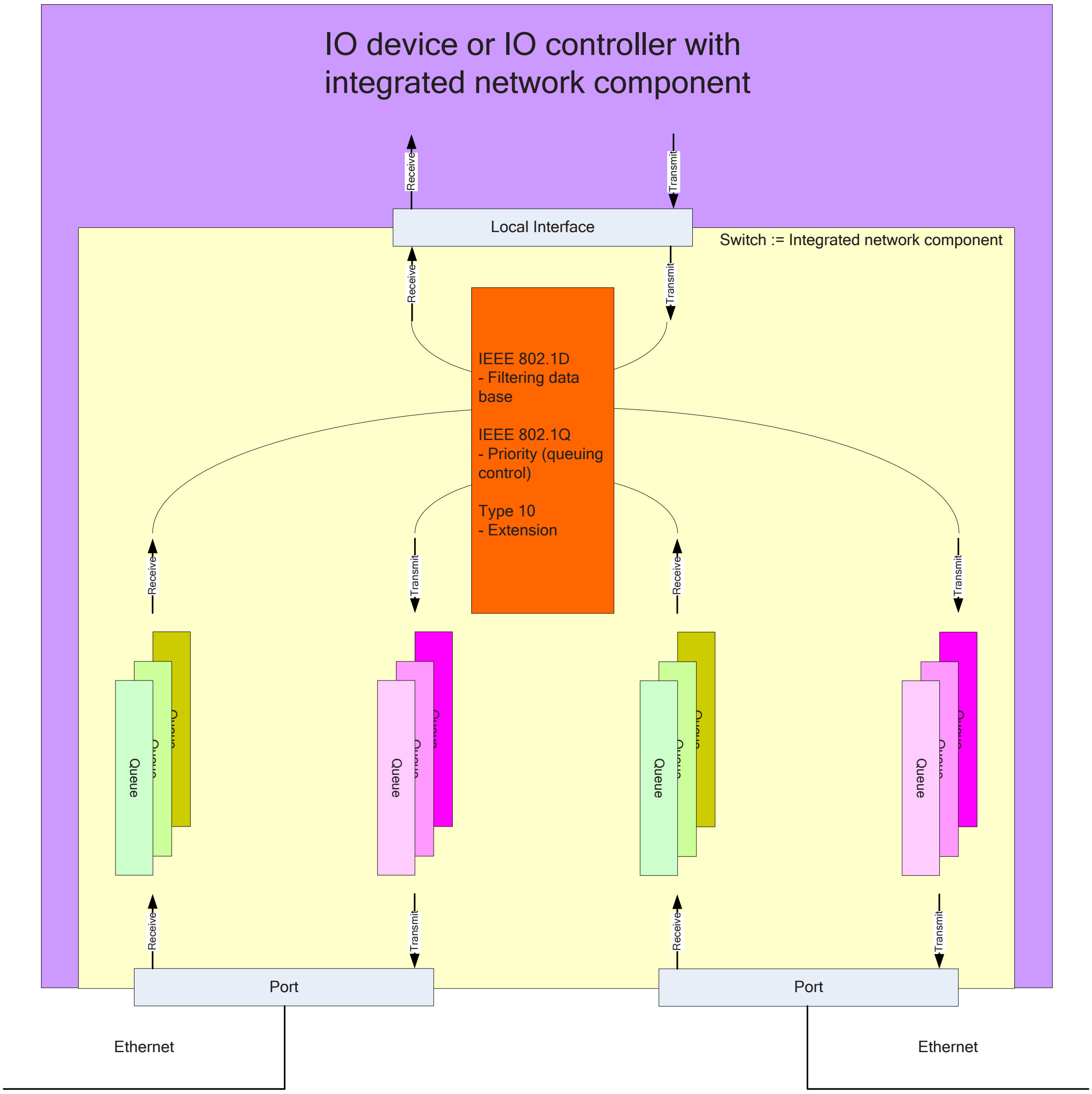

Figure A.14 – Example of a switch structure

All calculation is done in assumption,

- that the buffer capability of the used switches is always sufficient, and
- the priority queue control is available.

A.3 CPF 4/3 P-NET on IP – Performance indicator calculation

A.3.1 Application scenario

The application scenario for the consistent set of performance indicators has been selected for a typical configuration for factory automation. The complete application would typically have more nodes than shown in Figure A.15, both for control and IO handling. These nodes are either connected directly to the RTE nodes or via a P-NET network. Only the RTE nodes are shown in Figure A.15.

Thirty RTE end-stations (numbered from N1 to N30) are connected by means of 4 switches, as shown in Figure A.15, in an RTE network containing switches. All RTE nodes can communicate to any of the RTE nodes.

A.3.2 Delivery time calculation

The worst-case situation for calculating the Delivery time occurs when all 29 RTE end-stations (N1 to N29) are sending to the same receiver (N30) using the maximum packet size. The example for calculating the worst-case is given for Sender N1.

End-station-to-switch link is 10 Mbit/s.

Switch-to-switch link is 100 Mbit/s.

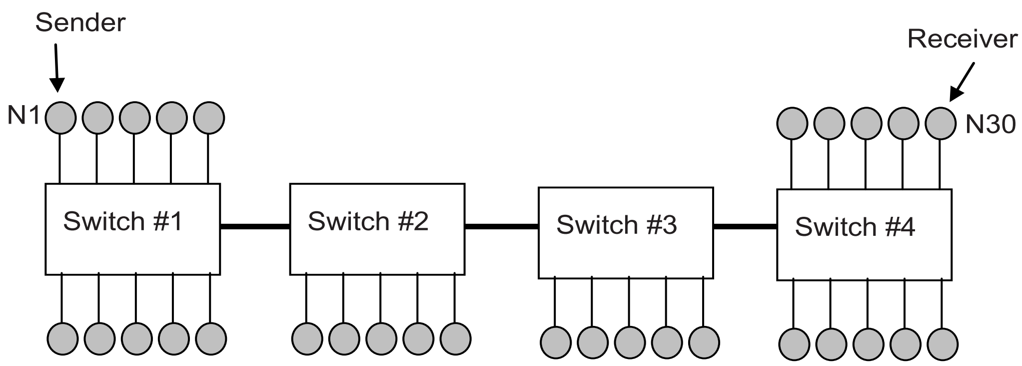

Figure A.15 – Application configuration

Delivery time can now be calculated by inserting the application-dependent constants for the selected scenario into the Formula (A.1).

$$DT = STTs + SSTr + NoNt\ (ttES + pd + QTES) + cd + \sum_{i=1}^{NoS-1}(NoNs(i)(NoS - i)(ttSS + pd + QTSS)) \qquad (A.1)$$

DT = 1 250 + 250 + 30(114,4 + 7 + 9,4) + 1

10 × 3 × (11,44 + 7 + 0,944) +

5 × 2 × (11,44 + 7 + 0,944) +

5 × 1 × (11,44 + 7 + 0,944)

DT = 6,3 µs

where

cd	is the cable delay time (200m) = 1 µs;
DT	is the delivery time;
NoNs[1]	is the number of RTE end-stations connected to switch No 1 = 10;
NoNs[2]	is the number of RTE end-stations connected to switch No 1 = 5;
NoNs[3]	is the number of RTE end-stations connected to switch No 1 = 5;
NoNs[4]	is the number of RTE end-stations connected to switch No 1 = 10;
NoNt	is the number of RTE end-stations, in total = 30;
NoS	is the number of switches in the path from sender to receiver = 4;
pd	is the propagation delay within a switch = 7 µs;
QTES	is the Ethernet enforced quiet time on end-station to switch link (10 Mbit/s) = 9,4 µs;
QTSS	is the Ethernet enforced quiet time on switch-to-switch link (100 Mbit/s) = 0,94 µs;
STTr	is the receiver stack transversal time including Phy and MAC = 250 µs;
STTs	is the sender stack transversal time including Phy and MAC access interval restriction = 1 250 µs;
ttES	is the P-NET transfer time RTE end station to switch at maximum APDU size (10 Mbit/s) = 114,4 µs;
ttSS	is the P-NET transfer time switch-to-switch at maximum APDU size (100 Mbit/s) = 11,44 µs.

The delivery time is increased with a timeout value in the event of a lost frame. The timeout value is application-dependent, and can be configured for each network in an application. The typical timeout value is 100 ms.

A.3.3 Non-RTE throughput calculation

Maximum RTE traffic on the switch-to-switch line, appears when all 20 external RTE end-stations (N1 to N20) are sending to the same receiver (N30) using maximum packet size. The remaining bandwidth is available for non-RTE traffic.

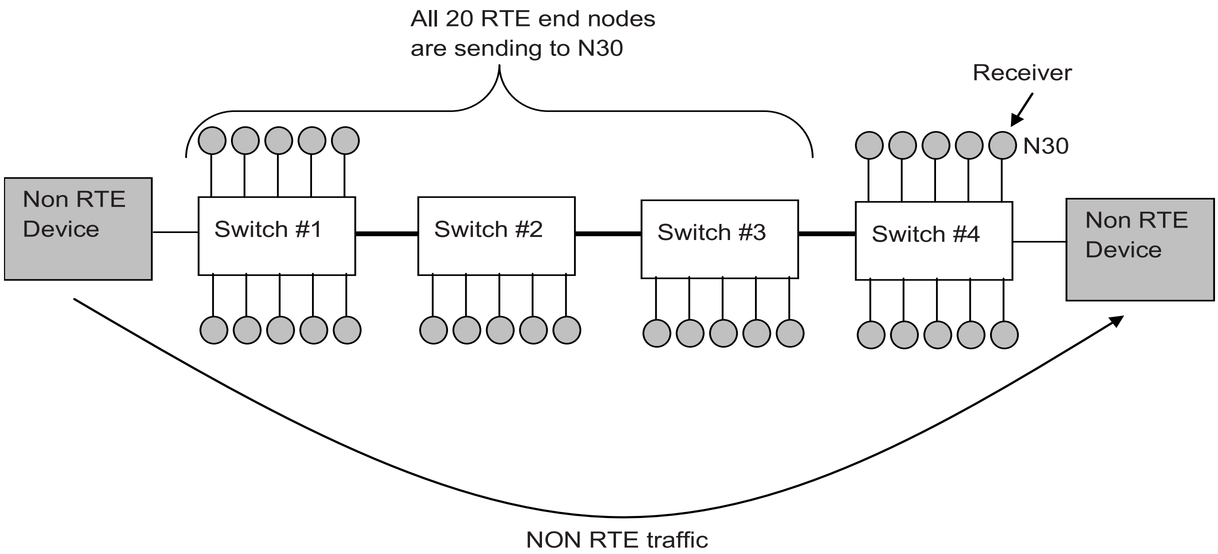

Figure A.16 – Non-RTE throughput calculation

The RTE load calculation is performed, using Formula (A.2).

$$Max\ RTE\ load = NoEN\ (\ ttSS + QTss) \qquad (A.2)$$

$$Max\ RTE\ load = 20(11{,}44+0{,}94) = 250\ \mu s$$

where

NoEN	is the number of RTE end-stations on the external switches = 20;
ttSS	is the transmission time for a maximum APDU on a switch-to-switch link = 11,44 µs;
QTss	is the enforced Ethernet quiet time on a switch-to-switch ink = 0,94 µs.

The maximum RTE load is 250 µs and due to the access restriction for a sender, this load can only be established once for every single ms.

This leaves 750 µs to the non-RTE bandwidth for every 1 000 µs, equivalent to 75 %.

A.3.4 Non time-base synchronization accuracy

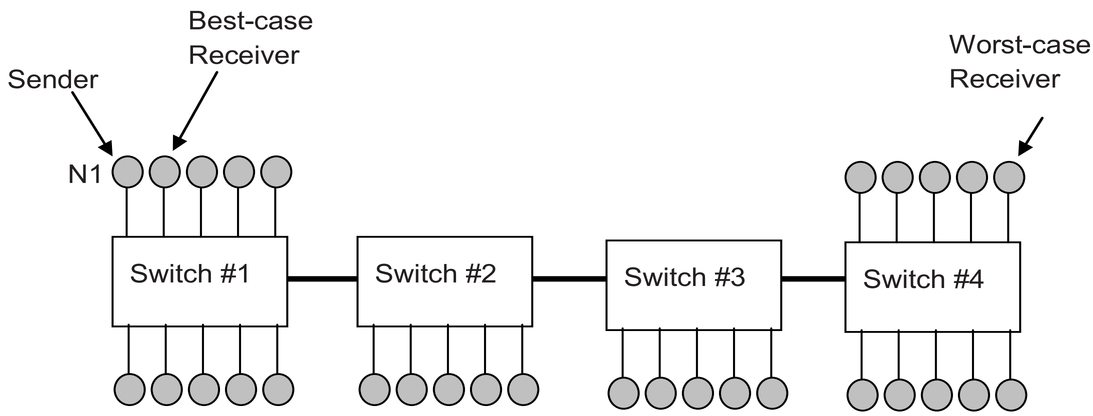

Figure A.17 – Non time-base synchronization accuracy

The non-time-base synchronization accuracy is calculated as the time difference between the best-case delivery time and the worst-case delivery time of a broadcasted "Super-Global-Variable". Calculation of non-time-base synchronization accuracy is shown in Formula (A.4).

Sender N1 is broadcasting a “Super-Global-Variable” message. A node on Switch #1 will obtain the best-case delivery time, whereas nodes on Switch #4 will have a worst-case delivery time, as shown in Figure A.17.

Delivery time to worst-case receiver will be 6 300 µs. See delivery time calculation in Formula (A.1).

Best case delivery time = SOT + ttESmin + pd + ttESmin + STTr (A.3)

*Best case delivery time = 250 + 57 + 7 +57 + 250 = 621 µ*s

where

SOT	is the sender stack transversal time. Best case without access restriction = 250 µs;
ttES	is the transmission time for a minimum APDU on 10 Mbit/s = 57 µs;
pd	is the propagation delay within a switch = 7 µs;
STTr	is the receiver stack transversal time including Phy and MAC = 250 µs.

Non-time-base synchronization accuracy = *DT – DTbest* (A.4)

Non-time-base synchronization accuracy = *6 300 – 621 = 5 679 ms*

where

DT	is the delivery time = 6,3 ms;
DTbest	is the best-case delivery time = 621 µs.

A.3.5 RTE throughput calculation

RTE throughput is calculated as a device’s maximum transmission rate of 1 000 frames/s.

Each frame can contain an APDU of variable size. The minimum RTE throughput is calculated by using Formula (A.5).

Minimum RTE throughput = FS x APDUmin (A.5)

Minimum RTE throughput = 1 000 x 5 = 5 000 octet/s

where

FS	is the number of frames allowed to be sent per second for one RTE end-station: 1 frame / ms = 1 000 frames / second;
APDUmin	is the minimum APDU size = 5 octets.

The maximum RTE throughput is calculated by using Formula (A.6).

Maximum RTE throughput = FS x APDUmax (A.6)

Maximum RTE throughput = 1 000 x 64 = 64 000 octets/s

where

FS	is the number of frames allowed to be sent per second for one RTE end-station: 1 frame / ms = 1 000 frames / second;
APDUmax	is the maximum APDU size = 64 octets.

A.3.6 CPF 4/3, Derivation of delivery time formula

The derivation of delivery time formula is composed of 6 elements:

(N1 frame to Switch1) + (N1..N10 frames to Switch 2) + (N1..15 frames to Switch 3) + (N1..N20 frames to Switch 4) + (N1..N29 frames from Switch 4 to N30) + (cable delay from N1 to N30), as shown in Formula (A.7).

STTs + ttES + pd + QTES + (A.7)

NoNs(1) x (ttSS + pd + QTSS) +

(NoNs(1)+NoNs(2))(ttSS + pd + QTSS) +

(NoNs(1)+NoNs(2) + NoNs(3))(ttSS + pd + QTSS) +

STTr + (NoNt-1)(ttES + pd +QTES) +

cd

=

Element 1, 5 and 6 are combined into:

STTs + STTr + NoNt(ttES + pd + QTES) + cd

Elements 2,3 and 4 are combined into:

$$\sum_{i=1}^{NoS-1}(NoNs(i)(NoS-i)(ttSS+pd+QTSS))$$

This gives the formula for Delivery time:

$$DT = STTs + STTr + NoNt\ (ttES + pd + QTES) + cd$$
$$\sum_{i=1}^{NoS-1}(NoNs(i)(NoS-i)(ttSS+pd+QTSS))$$

where

cd	is the cable delay time;
DT	is the delivery time;
NoNs[x]	is the number of RTE end-stations connected to switch No x. This includes number of RTE end-stations connected to the switch by other switches, which are not included in the path from sender to receiver. Switches are numbered as #1 at senders connection up to #NoS at the receivers connection;
NoNt	is the number of RTE end-stations, in total;
NoS	is the number of switches in the path from sender to receiver;
pd	is the propagation delay within a switch;
QTES	is the Ethernet enforced quiet time on end-station to switch link;

QTSS	is the Ethernet enforced quiet time on switch-to-switch link;
STTr	is the receiver stack transversal time including Phy and MAC;
STTs	is the sender stack transversal time including Phy and MAC access interval restriction;
ttES	is the P-NET transfer time RTE end-station to switch at maximum APDU size;
ttSS	is the P-NET transfer time switch-to-switch at maximum APDU size.

A.3.7 CPF 4/3, Ethernet characteristics

The size of an Ethernet frame for P-NET on IP is calculated by using Formula (A.8).

$$Ethernet\ frame\ size = Pa + Sadr + Dadr + Type + CRC + IPoh + UDPoh + Pnet \qquad (A.8)$$

where

Pa	is the Ethernet preamble of 8 octets;
Sadr	is the Ethernet source address of 6 octets;
Dadr	is the Ethernet destination address of 6 octets;
Type	is the Ethernet type of 2 octets;
CRC	is the Ethernet sum check of 4 octets;
IPoh	is the IP overhead of 20 octets;
UDPoh	is the UDP overhead of 8 octets;
Pnet	is the P-NET frame of variable size.

The Ethernet frame size is defined to be at least 72 octets. Since only the P-NET part of the Ethernet frame is variable, this means that a P-NET frame must occupy at least 18 octets, whether needed or not.

$$Transmission\ time = (NoO \times BpO) / Bps \qquad (A.9)$$

where

NoO	is the number of octets in a frame;
BpO	is the number of bits per octet to send = 8;
Bps	is the number bits send per second (transmission speed).

Using Formula (A.9) for calculating transmission time, the P-NET transmission times can be calculated for 10 Mbit/s:

The P-NET transmission time for the smallest frame up to 18 octets is 57,6 µs.

The P-NET transmission time for the largest RTE frame (Pnet = 70 octets) is 99,2 µs.

The P-NET transmission time for the largest Ethernet P-NET frame with routing information (Pnet = 89 octets) is 114,4 µs.

Enforced quiet time between Ethernet frames for 10 Mbit/s is 9,4 µs.

Cable delay: max allowed length of each cable connection is 100 m. A typical propagation speed is 2x10E8 m/s. This gives a max cable delay of 0,5 µs for each cable connection.

Bibliography

ISO/IEC/TR 10000-1:1998, *Information technology – Framework and taxonomy of International Standardized Profiles – Part 1: General principles and documentation framework*

ISO/IEC TR 8802-1:2001, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 1: Overview of Local Area Network Standards*

ISO/IEC 9646 (all parts), *Information technology – Open Systems Interconnection – Conformance testing methodology and framework*

ISO 15745-1, *Industrial automation systems and integration – Open systems application integration framework – Part 1: Generic reference description*

CAE Specification, *X/Open DCE: Remote Procedure Call, X/Open Company Limited, Reading, Berkshire, UK*, 1994. ISBN 1-85912-041-5.

(available online from the OSF as C709, DCE 1.1: Remote Procedure Call, at <http://www.opengroup.org>)

ODVA: THE CIP NETWORKS LIBRARY – Volume 1: *Common Industrial Protocol (CIP™) – Edition 3.13, November 2012*, available at <http://www.odva.org>

ODVA: THE CIP NETWORKS LIBRARY – Volume 2: *EtherNet/IP™ Adaptation of CIP – Edition 1.14, November 2012*, available at <http://www.odva.org>

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