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INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Industrial networks – Profiles –
Part 2-2: Additional real-time fieldbus profiles based on ISO/IEC/IEEE 8802-3 – CPF 2**

**Réseaux industriels – Profils –
Partie 2-2: Profils de bus de terrain supplémentaires pour les réseaux en temps réel fondés sur l'ISO/IEC/IEEE 8802-3 – CPF 2**

IEC 61784-2-2:2023-03(en-fr)

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NOTE Combinations of protocol types are specified in the IEC 61784-1 series and the IEC 61784-2 series.

IEC 61784-2-2 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation. It is an International Standard.

This first edition, together with the other parts of the same series, cancels and replaces the fourth edition of IEC 61784-2 published in 2019. This first edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC 61784-2:2019:

a) split of the original IEC 61784-2 into several subparts, one subpart for the material of a generic nature, and one subpart for each Communication Profile Family specified in the original document;

b) addition of two DLL protocol management objects;

c) addition of profile information removed from the Type standards.

The text of this International Standard is based on the following documents:

Draft	Report on voting
65C/1209/FDIS	65C/1237/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts of the IEC 61784-2 series, published under the general title *Industrial networks – Profiles – Part 2: Additional real-time fieldbus profiles based on ISO/IEC/IEEE 8802-3*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

INTRODUCTION

The IEC 61784-2 series provides additional Communication Profiles (CP) to the existing Communication Profile Families (CPF) of the IEC 61784-1 series 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/IEEE 8802-3 – commonly known as Ethernet. These RTE communication networks use provisions of ISO/IEC/IEEE 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/IEEE 8802-3, 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 the 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 can 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, whose values will be provided with RTE devices based on communication profiles specified in the IEC 61784-2 series, enable the user to match network devices with application-dependent performance requirements of an RTE network.

INDUSTRIAL NETWORKS – PROFILES –

Part 2-2: Additional real-time fieldbus profiles based on ISO/IEC/IEEE 8802-3 – CPF 2

1 Scope

This part of IEC 61784-2 defines extensions of Communication Profile Family 2 (CPF 2) for Real-Time Ethernet (RTE). CPF 2 specifies a set of Real-Time Ethernet (RTE) communication profiles (CPs) and related network components based on the IEC 61158 series (Type 2), ISO/IEC/IEEE 8802-3 and other standards.

For each RTE communication profile, this document also specifies the relevant RTE performance indicators and the dependencies between these RTE performance indicators.

NOTE 1 All CPs are based on standards or draft standards or International Standards published by the IEC or on standards or International Standards established by other standards bodies or open standards processes.

NOTE 2 The RTE communication profiles use ISO/IEC/IEEE 8802-3 communication networks and its related network components or IEC 61588 and in some cases amend those standards to obtain RTE features.

NOTE 3 Some CPs of CPF 2 are specified in IEC 61784-1-2.

2 Normative references

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

NOTE All parts of the IEC 61158 series, as well as the IEC 61784-1 series and the IEC 61784-2 series, 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 61158 (all parts), *Industrial communication networks – Fieldbus specifications*

IEC 61158-2:2023, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 61158-3-2:2023, *Industrial communication networks – Fieldbus specifications – Part 3-2: Data-link layer service definition – Type 2 elements*

IEC 61158-4-2:2023, *Industrial communication networks – Fieldbus specifications – Part 4-2: Data-link layer protocol specification – Type 2 elements*

IEC 61158-5-2:2023, *Industrial communication networks – Fieldbus specifications – Part 5-2: Application layer service definition – Type 2 elements*

IEC 61158-6-2:2023, *Industrial communication networks – Fieldbus specifications – Part 6-2: Application layer protocol specification – Type 2 elements*

IEC 61588:2021, *Precision clock synchronization protocol for networked measurement and control systems*

IEC 61784-1-2:2023, *Industrial networks – Profiles – Part 1-2: Fieldbus profiles – Communication Profile Family 2*

IEC 61784-2-0:2023, *Industrial networks – Profiles – Part 2-0: Additional real-time fieldbus profiles based on ISO/IEC/IEEE 8802-3 – General concepts and terminology*

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

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

ISO/IEC/IEEE 8802-3, *Telecommunications and exchange between information technology systems – Requirements for local and metropolitan area networks – Part 3: Standard for Ethernet*

IEEE Std 802-2014, *IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture*

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

IEEE Std 802.1AS-2020, *IEEE Standard for Local and Metropolitan Area Networks – Timing and Synchronization for Time-Sensitive Applications*

IEEE Std 802.1Q-2018, *IEEE Standard for Local and Metropolitan Area Networks – Bridges and Bridged Networks*

IETF RFC 768, J. Postel, *User Datagram Protocol*, August 1980, available at https://www.rfc-editor.org/info/rfc768 [viewed 2022-02-18]

IETF RFC 791, J. Postel, *Internet Protocol*, September 1981, available at https://www.rfc-editor.org/info/rfc791 [viewed 2022-02-18]

IETF RFC 792, J. Postel, *Internet Control Message Protocol*, September 1981, available at https://www.rfc-editor.org/info/rfc792 [viewed 2022-02-18]

IETF RFC 793, J. Postel, *Transmission Control Protocol*, September 1981, available at https://www.rfc-editor.org/info/rfc793 [viewed 2022-02-18]

IETF RFC 826, D. Plummer, *An Ethernet Address Resolution Protocol: Or Converting Network Protocol Addresses to 48.bit Ethernet Address for Transmission on Ethernet Hardware*, November 1982, available at https://www.rfc-editor.org/info/rfc826 [viewed 2022-02-18]

IETF RFC 894, C. Hornig, *A Standard for the Transmission of IP Datagrams over Ethernet*, April 1984, available at https://www.rfc-editor.org/info/rfc894 [viewed 2022-02-18]

IETF RFC 1112, S.E. Deering, *Host Extensions for IP Multicasting*, August 1989, available at https://www.rfc-editor.org/info/rfc1112 [viewed 2022-02-18]

IETF RFC 1122, R. Braden, *Requirements for Internet Hosts – Communication Layers,* October 1989, available at https://www.rfc-editor.org/info/rfc1122 [viewed 2022-02-18]

IETF RFC 1123, R. Braden, *Requirements for Internet Hosts – Application and Support,* October 1989, available at https://www.rfc-editor.org/info/rfc1123 [viewed 2022-02-18]

IETF RFC 1127, R.T. Braden, *Perspective on the Host Requirements RFCs,* October 1989, available at https://www.rfc-editor.org/info/rfc1127 [viewed 2022-02-18]

IETF RFC 2236, W. Fenner, *Internet Group Management Protocol, Version 2*, November 1997, available at https://www.rfc-editor.org/info/rfc2236 [viewed 2022-02-18]

IETF RFC 2544, S. Bradner, J. McQuaid, *Benchmarking Methodology for Network Interconnect Devices*, March 1999, available at https://www.rfc-editor.org/info/rfc2544 [viewed 2022-02-18]

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 IEC 61784-2-0, ISO/IEC/IEEE 8802-3, IEEE Std 802-2014, IEEE Std 802.1AB-2016, IEEE Std 802.1AS-2020 and IEEE Std 802.1Q-2018 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

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

3.2 Abbreviated terms and acronyms

For the purposes of this document, abbreviated terms and acronyms defined in IEC 61784-2-0 and the following apply.

CP	Communication Profile [according to IEC 61784-1-0]
CPF	Communication Profile Family [according to IEC 61784-1-0]
ICMP	Internet Control Message Protocol (see IETF RFC 792)
IETF	Internet Engineering Task Force
IP	Internet Protocol (see IETF RFC 791)
LLDP	Link Layer Discovery Protocol (see IEEE Std 802.1AB-2016)
PI	Performance indicator
pps	Packets per second
PTP	Precision Time Protocol (see IEC 61588)
RSTP	Rapid Spanning Tree Algorithm and Protocol (see IEEE Std 802.1Q-2018)
TCP	Transmission Control Protocol (see IETF RFC 793)
UDP	User Datagram Protocol (see IETF RFC 768)

3.3 Symbols

For the purposes of this document, symbols defined in IEC 61784-2-0 and Table 1 apply.

NOTE Definitions of symbols in this Subclause 3.3 do not use the italic font, as they are already identified as symbols.

Table 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

3.4 Conventions

For the purposes of this document, the conventions defined in IEC 61784-2-0 apply.

4 CPF 2 (CIP™[1]) – RTE communication profiles

4.1 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).

[1] 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 with this profile does not require use of the trade name CIP™. Use of the trade name CIP™ requires permission from ODVA, Inc.

This document defines two RTE communication profiles.

– Profile 2/2 EtherNet/IP™[2]

  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/IEEE 8802-3 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 allows using it also for the most demanding applications.

NOTE 1 See IEC 61784-1-2, Annex A, 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.

4.2 CP 2/2

4.2.1 Physical layer

See IEC 61784-1-2, 4.3.1.

4.2.2 Data-link layer

See IEC 61784-1-2, 4.3.2.

4.2.3 Application layer

See IEC 61784-1-2, 4.3.3.

4.2.4 Performance indicator selection

4.2.4.1 Performance indicator overview

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

Table 2 – 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	–

[2] 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 with this profile does not require use of the trade name EtherNet/IP™. Use of the trade name EtherNet/IP™ requires permission from ODVA, Inc.

4.2.4.2 Performance indicator dependencies

4.2.4.2.1 Dependency matrix

Table 3 shows the dependencies between performance indicators for CP 2/2.

Table 3 – 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	

4.2.4.2.2 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).

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

$$CD_i = PD_i \times CL_i \tag{2}$$

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

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 IETF 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 and the 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.

4.2.4.2.3 Number of end-stations

With regard to star topology, this document 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.

4.2.4.2.4 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.

4.2.4.2.5 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.

4.2.4.2.6 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 IEC 61784-2-0, 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).

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