IEC 61784-2-4

Edition 1.0 2023-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Industrial networks – Profiles –
Part 2-4: Additional real-time fieldbus profiles based on ISO/IEC/IEEE 8802-3 – CPF 4**

**Réseaux industriels – Profils –
Partie 2-4: Profils de bus de terrain supplémentaires pour les réseaux en temps réel fondés sur l'ISO/IEC/IEEE 8802-3 – CPF 4**

IEC 61784-2-4:2023-03(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 61784-2-4 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.

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- withdrawn,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 2-4: Additional real-time fieldbus profiles based on ISO/IEC/IEEE 8802-3 – CPF 4

1 Scope

This part of IEC 61784-2 defines extensions of Communication Profile Family 4 (CPF 4) for Real-Time Ethernet (RTE). CPF 4 specifies a Real-Time Ethernet (RTE) communication profile (CP) and related network components based on the IEC 61158 series (Type 4), 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 profile uses ISO/IEC/IEEE 8802-3 communication networks and its related network components and in some cases amend those standards to obtain RTE features.

NOTE 3 A CP of CPF 4 is specified in IEC 61784-1-4.

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 61158-3-4:2023, *Industrial communication networks – Fieldbus specifications – Part 3-4: Data-link layer service definition – Type 4 elements*

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

IEC 61158-5-4:2023, *Industrial communication networks – Fieldbus specifications – Part 5-4: Application layer service definition – Type 4 elements*

IEC 61158-6-4:2023, *Industrial communication networks – Fieldbus specifications – Part 6-4: Application layer protocol specification – Type 4 elements*

IEC 61784-1-4:2023, *Industrial networks – Profiles – Part 1-4: Fieldbus profiles – Communication Profile Family 4*

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*

TIA-485-A:1998, *Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems*

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

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*

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]

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]
CRC	Cyclic Redundancy Check
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)
NoS	Number of Switches
Phy	PHY Physical layer entity sublayer (see ISO/IEC/IEEE 8802-3)
PI	Performance indicator
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 4 symbols

Symbol	Definition	Unit
cd	Cable delay (Maximum on 100 m)	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

3.4 Conventions

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

4 CPF 4 (P-NET) – RTE communication profiles

4.1 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®[1].

– 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 TIA-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*

– 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/IEEE 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 61784-1-4, whereas profile 4/3 is described in this document.

4.2 CP 4/3, P-NET on IP

4.2.1 Physical layer

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

4.2.2 Data-link layer

4.2.2.1 DLL service selection

Table 2 holds the data-link layer service selections from IEC 61158-3-4 for this profile.

1 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 with 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.

Table 2 – 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, abbreviated terms 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	–

For this profile, DLS-user data size can exceed 56 octets and hence the Data-field-format parameter can hold one octet or two octets of information, as described in IEC 61158-3-4, 4.7.2.11. The size of DLS-user data shall not exceed 1 024 octets.

Support for DLS-user data greater than 56 octets is configured in the IP-header of the frame in the first octet: 3 means DLS user data greater than 56 octets; 2 means DLS-user data up to 56 octets.

4.2.2.2 DLL protocol selection

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

Table 3 – 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	Data Link Protocol definition	YES	[a]
[a] A device shall provide at least the necessary protocol options to fulfil the supported services.			

For this profile, the Data-field-format field can hold one octet or two octets of information, as described in IEC 61158-4-4, 4.2.3.4.

4.2.3 Application layer

4.2.3.1 AL service selection

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

Table 4 – 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.

4.2.3.2 AL protocol selection

Table 5 holds the Application layer protocol selections from IEC 61158-6-4 for this profile.

Table 5 – 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. If the Service Write with SecureDataExchange is required in a device, the Service Method shall also be provided in order to perform the exchange of Nonce'es for creating and validating Signatures.

4.2.4 Performance indicator selection

4.2.4.1 Performance indicator overview

Table 6 provides an overview of CP 4/3 performance indicators.

Table 6 – CP 4/3: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	Application dependent
Number of end-stations	YES	Up to 125
Basic network topology	YES	—
Number of switches between end-stations	YES	Communication between switches shall 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	—

4.2.4.2 Performance indicator dependencies

4.2.4.2.1 Overview of performance indicators

Table 7 shows an overview of performance indicators applicable to CP 4/3.

Table 7 – 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 synchronization accurancy	Redundancy recovery time
Delivery time		YES 4.2.4.2.2	YES 4.2.4.2.4	YES 4.2.4.2.2	YES 4.2.4.2.2	NO	NO	YES 4.2.4.2.3
Number of end-stations	YES 4.2.4.2.2		NO	NO	YES 4.2.4.2.2	YES 4.2.4.2.2	NO	NO
Basic network topology	YES 4.2.4.2.4	NO		NO	NO	NO	NO	NO
Number of switches between end-stations	YES 4.2.4.2.2	NO	NO		YES 4.2.4.2.2	YES 4.2.4.2.2	YES 4.2.4.2.2	YES 4.2.4.2.3
Throughput RTE	YES 4.2.4.2.2	YES 4.2.4.2.2	NO	YES 4.2.4.2.2		NO	NO	YES 4.2.4.2.3
Non-RTE bandwidth	NO	YES 4.2.4.2.2	NO	YES 4.2.4.2.2	NO		NO	NO
Non-time-based synchronization accuracy	YES 4.2.4.2.5	NO	NO	YES 4.2.4.2.5	NO	NO		NO
Redundancy recovery time	NO	NO	NO	YES 4.2.4.2.3	NO	NO	NO	

4.2.4.2.2 Calculation of Delivery time

Delivery time is calculated according to Formula (1). Derivation of this formula is given in Clause A.6. Switches are numbered as #1 at senders connection up to #NoS at the receivers connection.

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

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.

4.2.4.2.3 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.

4.2.4.2.4 Basic network topology

When using WLAN, the total delay caused by wireless transmissions can 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.

4.2.4.2.5 Non time-base synchronization accuracy

The non time-base synchronization accuracy is calculated according to Formula (2).

$$\text{Non time-base synchronization accuracy} = DT - DTb \quad (2)$$

where

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

4.2.4.2.6 Throughput RTE

The throughput RTE is calculated according to Formulae (3) and (4).

$$\text{Minimum RTE Throughput} = FS \times minAPDUs \quad (3)$$

$$\text{Maximum RTE Throughput} = FS \times maxAPDUs \quad (4)$$

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.