

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE



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

**Réseaux de communication industriels – Profils –  
Partie 2: Profils supplémentaires des bus de terrain pour les réseaux temps  
réel basés sur l'ISO/CEI 8802-3**

WILSON



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Withdrawn

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## INDUSTRIAL COMMUNICATION NETWORKS – PROFILES –

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

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

This bilingual version (2014-11) corresponds to the English version, published in 2007-12.

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

|              |                  |
|--------------|------------------|
| FDIS         | Report on voting |
| 65C/469/FDIS | 65C/480/RVD      |

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

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under <http://webstore.iec.ch> in the data related to the specific publication. At that date this publication will be

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- withdrawn;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

The list of all the parts of the IEC 61784 series, under the general title *Industrial communication networks – Profiles* –, can be found on the IEC web site.

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

## 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 – 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, 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, IEC 61158 series, and IEC 61784-1;
- RTE solutions that are able to run in parallel with ISO/IEC 8802-3-based applications.

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

NOTE The RTE communication profiles use ISO/IEC 8802-3 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 61588:2004, *Precision clock synchronization protocol for networked measurement and control systems*

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

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

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

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

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

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

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 8802-2/Cor. 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 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 802.1AB, *IEEE Standard for Local and metropolitan area networks Station and Media Access Control Connectivity Discovery*

IEEE 802.1D, *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 *IEEE Standard for Information technology – Telecommunications and information exchange between systems – IEEE standard for Local and metropolitan area networks – Virtual bridged local area networks*

IEEE 802.3-2002: *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 1 Compliance with future editions of this standard will need checking.

NOTE 2 IEEE 802.3-2002 includes extensions to ISO/IEC 8802-3:2000. When a next edition of ISO/IEC 8802-3 is available the references to IEEE 802.3-2002 will be replaced if appropriate.

IEEE Std 802.3ab, *Information technology – telecommunications and information exchange between systems – local and metropolitan area networks – Specific requirements. Supplement to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and physical layer specifications – Physical layer parameters and specifications for 1000 Mb/s operation over 4-pair of category 5 balanced copper cabling, type 1000BASE-T*

IEEE Std 802.11g, *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 – Amendment 4: Further higher data rate extension in the 2,4 GHz band*

IEEE Std 802.11h, *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 – Amendment 5: Spectrum and transmit power management extensions in the 5 GHz band in Europe*

IEEE Std 802.11e, *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 – Amendment 8: Medium Access Control (MAC) quality of service enhancements*

IEEE Std 802.11i, *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 – Amendment 6: Medium Access Control (MAC) security enhancements*

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)*

Internet Engineering Task Force (IETF), Request for Comments (RFC):

**RFC 768, User Datagram Protocol**

(available at <<http://www.ietf.org/rfc/rfc0768.txt>>)

**RFC 791, Internet Protocol**

(available at <<http://www.ietf.org/rfc/rfc0791.txt>>)

**RFC 792, Internet Control Message Protocol**

(available at <<http://www.ietf.org/rfc/rfc0792.txt>>)

**RFC 793, Transmission Control Protocol**

(available at <<http://www.ietf.org/rfc/rfc0793.txt>>)

**RFC 826, Ethernet Address Resolution Protocol**

(available at <<http://www.ietf.org/rfc/rfc0826.txt>>)

**RFC 894, A standard for the Transmission of IP Datagrams over Ethernet Networks**

(available at <<http://www.ietf.org/rfc/rfc0894.txt>>)

**RFC 1112, Host Extensions for IP Multicasting**

(available at <<http://www.ietf.org/rfc/rfc1112.txt>>)

**RFC 1122, Requirements for Internet Hosts – Communication Layers**

(available at <<http://www.ietf.org/rfc/rfc1122.txt>>)

**RFC 1123, Requirements for Internet Hosts – Application and Support**

(available at <<http://www.ietf.org/rfc/rfc1123.txt>>)

**RFC 1127, A Perspective on the Host Requirements RFCs**

(available at <<http://www.ietf.org/rfc/rfc1127.txt>>)

**RFC 1213, Management Information Base for Network Management of TCP/IP-based internets: MIB-II**

(available at <<http://www.ietf.org/rfc/rfc1213.txt>>)

**RFC 1305, Network Time Protocol (Version 3)**

(available at <<http://www.ietf.org/rfc/rfc1305.txt>>)

**RFC 2131, Dynamic Host Configuration Protocol**

(available at <<http://www.ietf.org/rfc/rfc2131.txt>>)

**RFC 2236, Internet Group Management Protocol, Version 2**

(available at <<http://www.ietf.org/rfc/rfc2236.txt>>)

**RFC 2328, OSPF Version 2**

(available at <<http://www.ietf.org/rfc/rfc2328.txt>>)

**RFC 2544, Benchmarking Methodology for Network Interconnect Devices**

(available at <<http://www.ietf.org/rfc/rfc2544.txt>>)

**RFC 2988, Computing TCP's Retransmission Timer**

(available at <<http://www.ietf.org/rfc/rfc2988.txt>>)

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 and IEEE 802.1D, 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 [IEC 61918]

##### 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 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 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 [IEEE Std. 802.1Q]

##### 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)

[IEC 61918]

### 3.1.12

#### **link**

transmission path between two adjacent nodes

[derived from ISO/IEC 11801]

### 3.1.13

#### **master**

<CPF 16>

node which assigns the other nodes the right to transmit

### 3.1.14

#### **message**

ordered series of octets intended to convey information

[derived from ISO 2382-16.02.01]

NOTE Normally used to convey information between peers at the application layer.

### 3.1.15

#### **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

### 3.1.16

#### **node**

network entity connected to one or more links

NOTE A node may be either a switch, an end-station or an RTE end-station.

### 3.1.17

#### **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 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.

### 3.1.18

#### **real-time**

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

### 3.1.19

#### **real-time communication**

transfer of data in real time

### 3.1.20

#### **Real-Time Ethernet (RTE)**

ISO/IEC 8802-3-based network that includes real-time communication

NOTE 1 Other communication can be supported, providing the real-time communication is not compromised.

NOTE 2 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.

### 3.1.21

#### **ring**

active network where each node is connected in series to two other nodes  
[IEC 61918]

NOTE Ring may also be referred to as loop.

### 3.1.22

#### **router**

<CPF 10>

intermediate equipment that connects two or more subnetworks using a network layer relay function

### 3.1.23

#### **RTE end device**

device with at least one RTE end-station

### 3.1.24

#### **RTE end-station**

end-station with RTE capability

### 3.1.25

#### **schedule**

temporal arrangement of a number of related operations

### 3.1.26

#### **star**

network of three or more devices where all devices are connected to a central point  
[derived from IEC 61918]

### 3.1.27

#### **subnetwork**

<CPF 10>

part of a network that does not contain any routers

NOTE 1 A subnetwork consists of end stations, bridges and segments.

NOTE 2 Every end-station included in a subnetwork has the same IP network address.

### 3.1.28

#### **switch**

MAC bridge as defined in IEEE 802.1D

### 3.1.29

#### **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<br>[according to IEC 61784-1]        |
| CPF     | Communication Profile Family<br>[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 Identifier (see IEC 61158-6-10)                      |
| 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                                         |
| LAN     | Local Area Network                                         |
| LLC     | Logical Link Control                                       |
| LLDP    | Link Layer Discovery Protocol (see IEEE 802.1-AB)          |

|             |                                                                                           |
|-------------|-------------------------------------------------------------------------------------------|
| MAC         | Media Access Control                                                                      |
| MAC         | Media Access Control (see ISO/IEC 8802.3)                                                 |
| Mbit/s      | Million bits per second                                                                   |
| Moctets/s   | Million octets per second                                                                 |
| MCR         | Multicast communication relation                                                          |
| MIB         | Management Information base                                                               |
| MRP         | Medium redundancy protocol                                                                |
| MRRT        | Media redundancy for real-time                                                            |
| MRPD        | Media redundancy for planned duplication                                                  |
| ms          | milli seconds                                                                             |
| NoS         | Number of Switches                                                                        |
| NRT         | Non-real-time                                                                             |
| OSPF        | Open Shortest Path First (see RFC 2328)                                                   |
| PDU         | Protocol Data Unit                                                                        |
| PhL         | Physical layer                                                                            |
| Phy         | PHY Physical layer entity sublayer (see ISO/IEC 8802.3)                                   |
| 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                                                                        |
| RTO         | Retransmission Time Out<br>[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 RFC 1213)                                         |
| TCC         | Time-Critical Cyclic                                                                      |
| TCP         | Transmission Control Protocol (see RFC 793)                                               |
| TOS         | Type of Service                                                                           |
| UDP         | User Datagram Protocol (see 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_N RTE_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 <sub>r</sub>       | Receiver stack delay                                             | µs     |
| SD <sub>s</sub>       | Sender stack delay                                               | µs     |
| SL                    | Switch latency                                                   | µs     |
| SPD                   | Switch processing delay                                          | µs     |
| T <sub>x_packet</sub> | 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 <sub>bit</sub> | Nominal bit duration (see 27.2 in IEC 61158-2)                          | µs     |
| t <sub>s</sub>   | 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 |

Withdrawn

### 3.3.6 CPF 11 symbols

| Symbol            | Definition                                                                                                                                                                                                                                | Unit      |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| BW <sub>CNT</sub> | Bandwidth used both for the communication scheduling and the protocol overhead                                                                                                                                                            | %         |
| BW <sub>NRT</sub> | Bandwidth used for the non-RTE communications                                                                                                                                                                                             | %         |
| BW <sub>RTE</sub> | Bandwidth used for the RTE communications                                                                                                                                                                                                 | %         |
| cd                | Cable delay                                                                                                                                                                                                                               | µs        |
| cdl               | Cable length total                                                                                                                                                                                                                        | km        |
| ct                | Cycle time                                                                                                                                                                                                                                | ms        |
| data              | Complete Ethernet frame                                                                                                                                                                                                                   | —         |
| DT <sub>H</sub>   | 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 <sub>L</sub>   | 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 <sub>M</sub>   | 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 <sub>HS</sub>  | Total volume of the high-speed cyclic data                                                                                                                                                                                                | octets    |
| DV <sub>LS</sub>  | Total volume of the low-speed cyclic data                                                                                                                                                                                                 | octets    |
| DV <sub>MS</sub>  | 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        |
| T <sub>h</sub>    | The high-speed transmission time period – the basic cycle_time (ct) of the TCC data service                                                                                                                                               | ms        |
| T <sub>HS</sub>   | Total sum of the frame transmit time, in which the TCC data frame conveys the high-speed cyclic data                                                                                                                                      | µs        |
| T <sub>l</sub>    | The Low-speed transmission time period                                                                                                                                                                                                    | ms        |
| T <sub>LS</sub>   | Total sum of the frame transmit time, in which the TCC data frame conveys the Low-speed Cyclic data                                                                                                                                       | µs        |
| T <sub>m</sub>    | The Medium-speed transmission time period                                                                                                                                                                                                 | ms        |
| T <sub>MAC</sub>  | 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 <sub>MS</sub>   | Total sum of the frame transmit time, in which the TCC data frame conveys the medium-speed cyclic data                                                                                                                                    | µs        |
| T <sub>NRT</sub>  | 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 <sub>h</sub> and is used for the standard Ethernet application on sporadic basis | µs        |
| TR <sub>HS</sub>  | Throughput RTE of the high-speed cyclic data                                                                                                                                                                                              | Moctets/s |
| TR <sub>LS</sub>  | Throughput RTE of the low-speed cyclic data                                                                                                                                                                                               | Moctets/s |
| TR <sub>MS</sub>  | Throughput RTE of the medium-speed cyclic data                                                                                                                                                                                            | Moctets/s |
| TR <sub>RTE</sub> | Throughput RTE, and the sum of TR <sub>HS</sub> , TR <sub>LS</sub> and TR <sub>MS</sub>                                                                                                                                                   | Moctets/s |
| T <sub>RTE</sub>  | 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 <sub>h</sub>                                                       | µs        |
| T <sub>SCH</sub>  | 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                                     | $\mu s$   |
| $t_{cd}$    | Cable delay                                           | $\mu s/m$ |
| $t_{cpdl}$  | Data copy delay within a slave                        | $\mu s$   |
| $t_{cycle}$ | Cycle time                                            | $\mu s$   |
| $t_D$       | Delivery time                                         | $\mu s$   |
| $t_{data}$  | Time to transmit the longest real-time Ethernet frame | $\mu s$   |

**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                                        | $\mu s$ |
| $T_C$      | Communication cycle time                                                                             | $\mu s$ |
| $T_D$      | Delivery time                                                                                        | $\mu s$ |
| $T_{FT,i}$ | RTE frames transmission time for RTE end-station $i$                                                 | $\mu s$ |
| $T_P$      | Processing time in the receiving end-station                                                         | $\mu s$ |
| $T_{RD,i}$ | Response delay of the RTE end-station $i$                                                            | $\mu s$ |
| $T_S$      | Communication cycle start delay                                                                      | $\mu s$ |
| $T_{SD,i}$ | Sum of all delays of infrastructure components (switches, hubs, cabling) for the RTE end-station $i$ | $\mu s$ |

### 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   |
| RMDData        | Redundancy management data                                        | octets   |
| RTData         | 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       |
| TSDData        | 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_if  | Delivery time when a frame is lost                                                  | µs     |
| DT_ifh | Delivery time when a frame is lost and the configuration is reliable with heartbeat | µs     |
| DT_ifp | Delivery time when a frame is lost and the configuration is reliable periodic       | µs     |
| DT_n   | Delivery time for the NACK message                                                  | µs     |
| 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   |

### 3.4 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                                                        |
| 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<sup>1</sup> as either

- Compliance to IEC 61784-2:2007 CPF n <Type>, or
- Compliance to IEC 61784-2 (Ed.1.0) CPF n <Type>.

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

- Compliance to IEC 61784-2:2007 CP n/n <Type>, or
- Compliance to IEC 61784-2 (Ed.1.0) 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.

<sup>1</sup> In accordance with ISO/IEC Directives.

## 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 cannot be violated. For example the indicator "Throughput RTE (which would use 90 % of the total bandwidth)" and "Throughput non-RTE (90 %)" cannot happen 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).

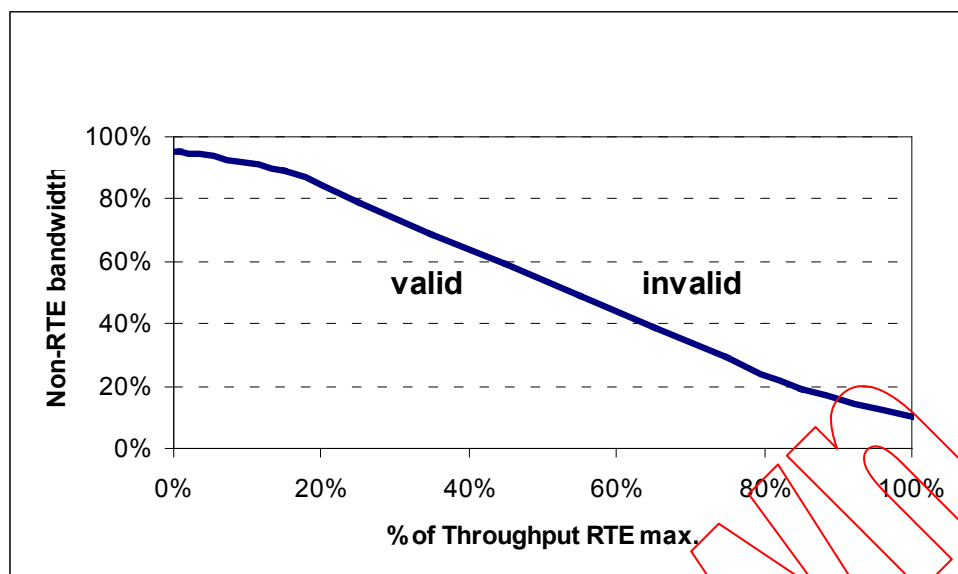


**Figure 1 – Example of graphical representation of consistent indicators**

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 Applications may 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.

NOTE 3 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.

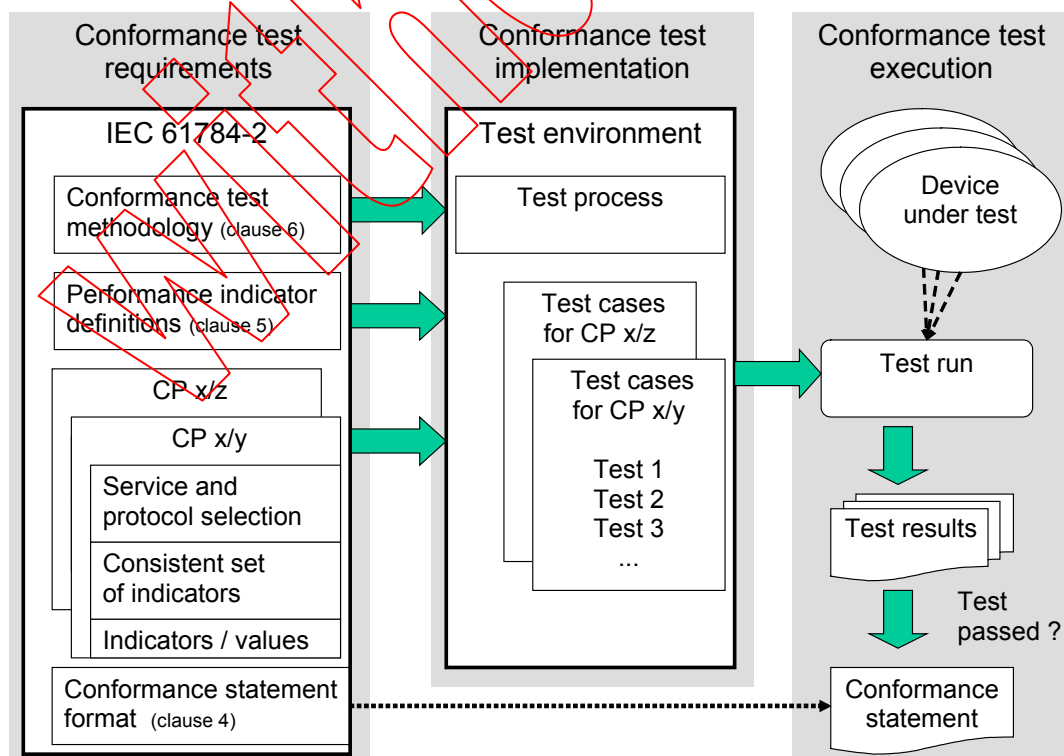


Figure 2 – Conformance test overview

## 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™<sup>2</sup>) – RTE communication profiles

### 7.1 General overview

Communication Profile Family 2 defines several communication profiles based on IEC 61158-2 through IEC 61158-6, protocol type 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™<sup>3</sup>

This profile contains a selection of AL, DLL and PhL services and protocol definitions from IEC 61158-4 through IEC 61158-6, protocol type 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 802.3-2002 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 61588:2004 allows using it also for the most demanding applications.

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

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

<sup>2</sup> CIP™ is a trade name of Open DeviceNet Vendor Association, Inc. This information is given for the convenience of users of this International Standard 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 Open DeviceNet Vendor Association, Inc.

<sup>3</sup> EtherNet/IP™ is a trade name of ControlNet International, Ltd. and Open DeviceNet Vendor Association, Inc. This information is given for the convenience of users of this International Standard 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 either ControlNet International, Ltd. or Open DeviceNet Vendor Association, Inc.

**Table 10 – CP 2/2: performance indicator 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: Performance indicator 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).

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

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

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

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).

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

where

*APDUsiz* 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).

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

$$\text{EN\_PR} = \text{EN\_TRTE\_PR} + \text{EN\_TNRTE\_PR} \leq \text{EN\_PR\_MAX} \quad (6)$$

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

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

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

where

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

$$EN\_TRTE\_PR = 2 \times 200 \text{ pps} + 3 \times 100 \text{ pps} = 700 \text{ pps}$$

$$EN\_PR = 700 \text{ pps} + 40 \text{ pps} = 740 \text{ pps}$$

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

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

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 performance indicators 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 <sup>6</sup> 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 profile is according to ISO/IEC 8802-3 and IEEE 802.3-2002.

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

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

## 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, IEEE 802.3-2002 and IEC 61588:2004.

### 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, IEEE 802.3-2002 and IEC 61588:2004.

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 and abbreviations     | YES      | —            |
| 4 – 5      | —                                                 | NO       | —            |
| 6          | Specific DLPDU structure, encoding and procedures | —        | —            |
| 6.1        | Modeling language                                 | YES      | —            |
| 6.2 – 6.13 | —                                                 | NO       | —            |
| 7          | Objects for station management                    | —        | See Table 14 |
| 8 – 9      | —                                                 | NO       | —            |
| 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      | —                                  |

### 7.3.3 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                |
| 5         | Data type ASE                                              | Partial  | Selection and restrictions are specified in IEC 61158-5-2 |
| 6         | Communication model specification                          | —        | —                                                         |
| 6.1       | Type 2 specific 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      | —                                                         |
| 6.2.1.3   | FAL management model ASE service specification             | YES      | —                                                         |
| 6.2.2     | Connection manager ASE                                     | YES      | Single class in this ASE                                  |
| 6.2.3     | Connection ASE                                             | NO       | —                                                         |
| 6.3       | AR's                                                       | —        | —                                                         |
| 6.3.1     | Overview                                                   | YES      | —                                                         |
| 6.3.2     | UCMM AR formal model                                       | YES      | —                                                         |
| 6.3.3     | Transport AR formal model                                  | Partial  | Transport ARs 0, 1, 2 and 3 only                          |
| 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                                    | 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      | 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)                                | YES      | —                                    |
| 9.3    | Connection-oriented ARPMs (transports)                     | Partial  | Transport classes 0, 1, 2 and 3 only |
| 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.

### 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: performance indicator 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           | Yes        | Requires switches capable to function as IEC 61588:2004 boundary clocks. |
| 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: performance indicator 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  $\mu$ s accuracy in a star network, it is necessary to use switches containing IEC 61588:2004 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  $\pm 100$  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 performance indicators for motion control**

| Performance indicator                   | Value                                     | Constraints                                              |
|-----------------------------------------|-------------------------------------------|----------------------------------------------------------|
| Delivery time                           | 130 $\mu$ s to 190 $\mu$ s                | —                                                        |
| Number of end-stations                  | 2 to 90                                   | Maximum number of ports in switches with boundary clocks |
| Number of switches between end-stations | 1 to 4                                    | Maximum number of cascaded boundary clocks               |
| Throughput RTE                          | 0 octets/s to $3,44 \times 10^6$ octets/s | —                                                        |
| Non-RTE bandwidth                       | 0 % to 100 %                              | —                                                        |
| Time synchronization accuracy           | $\leq 1$ $\mu$ s                          | —                                                        |

Withdrawn