Real-Time Ethernet in IEC 61784-2 and IEC 61158 series

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Abstract—**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.**

Real-Time Ethernet (RTE) communication systems 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, which values will be provided with RTE devices based on communication profiles specified in IEC 61784-2, enable the user to match network devices with application dependant performance requirements of an RTE network. Communication profiles within IEC 61784-2 refer to IEC 61158 series. The concept of IEC 61158 series, how the protocol and services are specified, is interpreted. Using the same concept to specify the different communication networks supports to build bridges between the different communication networks.

I. Standardization

Real-Time Ethernet profiles are specified in IEC 61784-2. Within International Electrotechnical Commission (IEC) exists several Technical Committees (TC) and Sub-Committees (SC). The responsible working group (WG) within SC65C is WG11. IEC SC65C is dealing with industrial networks. IEC SC65C WG11 specified the "Additional profiles for ISO/IEC 8802-3 based communication networks in real-time applications".

IEC 61784-2 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. Real-Time Ethernet provides the availability such as:

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

Real-time means the ability of a system to provide a required result in a bounded time. Synchronized actions require timeand/or clock synchronization. Efficient, frequent exchange of very small data records is typically performed by a cyclic data exchange with specific Quality of services.

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 IEC 61784-2, Clause 5), which values will be provided with RTE devices based on communication profiles specified in IEC 61784-2, enable the user to match network devices with application dependant performance requirements of an RTE network.

IEC 61784-2, 5.1 specifies basic principles of performance indicators required to express RTE performance of a CP. IEC 61784-2, 5.2 describes the view of application requirements. An application- dependant class could be used to find out a suitable CP.

IEC 61784 consists of the following parts:

Part 1: Profile sets for continuous and discrete manufacturing relative to fieldbus use in industrial control systems

Part 2: Additional profiles for ISO/IEC 8802□3 based communication networks in real-time applications

Part 3: Profiles for functional safety communications in industrial networks.

Part 4: Profiles for secure communications in industrial networks (Disbanded until IEC 62443 (IEC TC

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65/WG10) is ready).

Part 5: Profiles for digital data communications for measurement and control – Installation profiles for communication networks in industrial control systems.

IEC SC65C WG11 has been supported by 31 experts from 11 countries and 7 Liaison partners. Since 2003 in 8 meetings and using the electronic collaborative tools of IEC the WG11 send out the committee draft for vote (CDV) by April 2006.

The D-Liaison partners of WG11 are:

- IEC TC57 (Power Distribution, Utilities)
- ETG (EtherCAT)
- CC-Link
- PROFIBUS International
- SERCOS
- ODVA
- IAONA

The work plan is:

- FDIS in Jan 2007 (synchronized with IEC 61158, Ed.4)
- International Standard (IS) in 07/2007

IEC SC65C MT9 is the responsible working group or more precise the maintenance team (MT) to maintain IEC 61158 series. This series spefies the communication protocol and the physical layers.

II. Relations of CPF in IEC 61784-1 to type numbers in IEC 61158

The IEC 61158 series specifies 18 different fieldbus types in each of the parts of the series (Parts 2 to 6). As a result of the editorial harmonization work done by IEC, each Physical Layer (PhL), Data Link Layer (DLL) and Application Layer (AL) specification within IEC 61158 series is shown in a homogeneous way, see VI. The description of each layer offers, as far as possible, common views, concepts, definitions, and descriptive method.

This common approach has been adopted to assist users and implementers in understanding the several specifications. It is also intended to assist in comparing available products and their communications-related features.

IEC 61784-1 and IEC 61784-2 contain several communication profile families (CPF), which specify one or more communication profiles (CP). Such profiles identify, in a strict sense, type subsets of the IEC 61158 series. A CP can select one Physical Layer (PhL) or may support different PhL.

Profiles contained in IEC 61784-1 and IEC 61784-2 are constructed of references to IEC 61158-2 and 61158-3-tt through IEC 61158-6-tt, ISO/IEC 8802-3 and other IS or worldwide-accepted standards, as appropriate. Each profile is required to reference at least one part of IEC 61158-2 and 61158-3-tt through IEC 61158-6-tt.

IEC 61784-2 specifies additional profiles that 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.

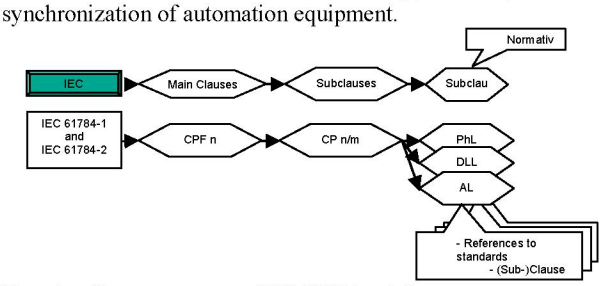

Figure 1 — Document structure of IEC 61784-1 and -2

IEC 61784-1 and IEC 61784-2 is structured by clauses to specify CPFs and within a Clause in subclauses to specify CPs by referencing IEC 61158 series and other standards, see Figure 1. Within a subclause specifying a CP it is mandatory to specify PhL, Data Link Layer (DLL), and Application Layer (AL) consecutively.

The communication networks listed in Table 1 started to provide a CPF in IEC 61784-2 as a Publicly Available Specification (PAS).

Table 1 — IEC/PAS for RTE

Family #	Technology Name	IEC/PAS NP #	
CPF2	Ethernet/IP	IEC/PAS 62413	
CPF3	PROFINET	IEC/PAS 62411	
CPF4	P-NET	IEC/PAS 62412	
CPF6	INTERBUS		
CPF10	VNET/IP	IEC/PAS 62405	New RTE
CPF11	TCnet	IEC/PAS 62406	
CPF12	EtherCAT	IEC/PAS 62407	
CPF13	ETHERNET Powerlink	IEC/PAS 62408	
CPF14	EPA	IEC/PAS 62409	
CPF15	MODBUS-RTPS	IEC/PAS 62030	
CPF16	SERCOS-III	IEC/PAS 62410	

Up to now 6 new candidates provided a CPF in IEC 61784-2 (CDV). Ethernet Powerlink did not provide material in time and according the agreed rules, so it is withdrawn from IEC 61784-2.

III. Added value compared to part 1

Conformance test is required for a compliance statement to IEC 61784-2. The rational is that Real-Time means a guarantee of the ability of a system to provide a required result in a bounded time.

The concept of this conformance test is to verify the capabilities of a device under test (DUT) against a consistent

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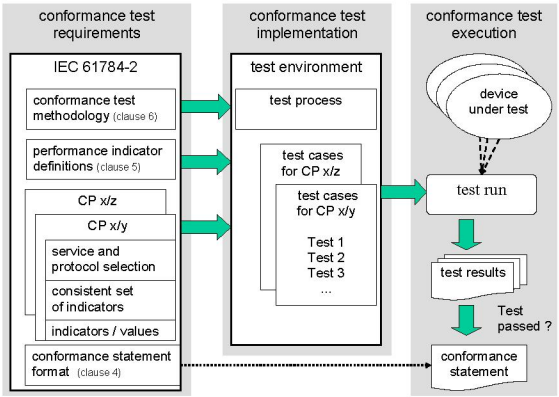
set of Performance Indicators (PI) of a CP. The conformance test shall assure the interoperability of devices which claim compliance with the same CP. Figure 2 gives an overview of the conformance test related to this part of IEC 61784.



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

Figure 2 — Conformance test overview

Test cases shall be developed in a way that tests are repeatable. 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.

IV. RTE 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 (PI) shall be used to specify capabilities of an RTE end device and a 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.

PIs 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 PIs is used to represent the RTE capabilities. Some of the PIs 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 %.

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.

PI represent:

- capabilities of an RTE end device,
- capabilities of an RTE communication network,
- as well as requirements of an application.

9 PI:

- Delivery time
- Number of end nodes
- Basic network topology
- Number of switches between end nodes
- Throughput RTE
- Non-RTE bandwidth
- Time synchronization accuracy
- Non time-based synchronization accuracy
- Redundancy recovery time

V. MCR FOR IEC 61158 ED.4

A maintenance cycle report (MCR) is the starting point of a revised IS. IEC 61158 series was published as Edition 3 in 2002. The next revised edition 4 should be published at the end of the 5 year maintenance cycle in 2007. The following changes in the document structure were agreed:

- IEC 61158 parts 3, 4, 5, and 6 will be split in type-specific subparts.
- No change of the document structure in IEC 61158-1, -2, as well as no change in IEC 61784-1.
- The type numbers and CPF numbers will remain.

Table 2 shows the assigned Type numbers and the associated CPFs.

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VI. CONCEPT OF IEC 61158 SERIES

A. *First concept:*

The complex communication task is divided into different layers based on an adaptation of ISO/IEC 7498, the ISO/OSI Basic Reference Model, thereby facilitating well-structured functions and interfaces (see Clause 6). This has the following benefits:

- decomposition of complex tasks;
- modular structure to adapt different technologies.

B. *Second concept:*

Each fieldbus type is composed of one or more layer specifications.

Most types include a number of services and protocol options that require an appropriate selection to support a working system. Compatible selections of options and services within one of the IEC 61158 fieldbus types are specified as standardized communication profiles in IEC 61784-1 and IEC 61784-2. Most of these profiles are supported by consortia or trade associations which are identified in the profile specification.

C. *Third concept:*

The physical, data-link and application layers are described in complementary ways, in terms of the offered services and the protocol which provides those services.

D. *Differences between service and protocol viewpoints*

The application layer structure is as follows:

— the "what" is described by application layer service elements (ASE); and

— the "how" is described by application layer relationships (AR).

The data-link layer structure is as follows:

— the "what" is described by data-link layer services and models; and

— the "how" is described by data-link layer protocol machines and medium access principles.

The physical layer is structured similarly, but, because its services are readily described, they occur in the same specification (IEC 61158-2) as the definitions of the physical protocols.

— The "what" is described by physical layer services and models, and

— The "how" is described by physical layer electromagnetic and mechanical specifications.

Figure 3 shows the concept of protocol and services.

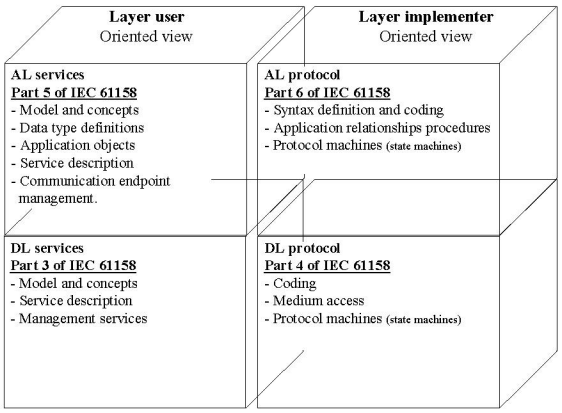

Figure 3 — Concept of protocol and services

VII. REFERENCES

The referenced ISO, IEC, and ISO/IEC documents are available over www.iso.ch or www.iec.ch.

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Table 2 — Overview of CPF, CP, and Types

Communication Profiles (CP) in IEC 61784			**Corresponding IEC 61158 Types to CP**		**D-Liaison**
Family CPF #	**Technology Name**	**61784-part#**	**CP#**	**Type #**	**Organiz**
1	Foundation Fieldbus	1	CP 1/1 H1	1,9	FF
		1	CP 1/2 HSE	5	
		1	CP 1/3 H2	1,9	
2	CIP	1	CP 2/1 ControlNet	2	ODVA
		1, 2	CP 2/2 EtherNet/IP		
		2	CP 2/21 EtherNet/IP time syn.	2	
		1	CP 2/3 DeviceNet	2	
3	PROFIBUS, PROFINET	1	CP 3/1 PROFIBUS DP	3	PI
		1	CP 3/2 PROFIBUS PA	3	
		1	CP 3/3 PROFINET CBA	10	
		2	CP 3/4 PROFINET IO CC-A	10	
		2	CP 3/5 PROFINET IO CC-B	10	
		2	CP 3/6 PROFINET IO CC-C	10	
4	P-NET	1	CP 4/1 P-NET RS-485	4	IPUO
		1	CP 4/2 P-NET RS-232	4	
		2	CP 4/3 P-NET on IP	4	
5	WorldFIP	1	CP 5/1 WorldFIP	7	—
		1	CP 5/2 WorldFIP with subMMS	7	
		1	CP 5/3 WorldFIP minimal for TCP/IP	7	
6	INTERBUS	1	CP 6/1 INTERBUS	8	—
		1	CP 6/2 INTERBUS TCP/IP	8	
		1	CP 6/3 INTERBUS minimal [subset of CP 6/1]	8	
		2	CP 6/4	8	
		2	CP 6/5	8	
		2	CP 6/6	8	
~~7~~	~~SwiftNet~~	~~1~~	~~CP 7/1 SwiftNet Transport~~	~~6~~	~~—~~
-	-	~~1~~	~~CP 7/2 SwiftNet Full stack~~	~~6~~	-
8	CC-Link	1	CP 8/1	18	CLPA
		1	CP 8/2	18	
		1	CP 8/3	18	
9	—	—	unused	—	—
10	VNET/IP	2	CP 10/1	17	—
11	TCnet	2	CP 11/1	11	—
		2	CP 11/2		
12	EtherCAT	2	CP 12/1	12	ETG
		2	CP 12/2		
13	ETHERNET Powerlink	2	CP 13/1	13	IAONA
14	EPA	2	CP 14/1	14	—
		2	CP 14/2		
15	MODBUS-RTPS	2	CP 15/1 MODBUS-TCP	15	MODBUS
		2	CP 15/2 MODBUS-RTPS		
16	SERCOS	1	CP 16/1 SERCOS-I	16	IGS
		1	CP 16/2 SERCOS-II	16	
		2	CP 16/3 SERCOS-III	19	

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