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Industrial communication networks — Fieldbus specifications

Part 6-22: Application layer protocol specification — Type 22 elements

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

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English version

**Industrial communication networks -
Fieldbus specifications -
Part 6-22: Application layer protocol specification -
Type 22 elements
(IEC 61158-6-22:2010)**

Réseaux de communication industriels -
Spécifications des bus de terrain -
Partie 6-22: Spécification des protocoles
des couches d'application -
Éléments de type 22
(CEI 61158-6-22:2010)

Industrielle Kommunikationsnetze -
Feldbusse -
Teil 6-22: Protokollspezifikation des
Application Layer (Anwendungsschicht) -
Typ 22-Elemente
(IEC 61158-6-22:2010)

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Foreword

The text of document 65C/607/FDIS, future edition 1 of IEC 61158-6-22, prepared by SC 65C, "Industrial networks", of IEC/TC 65, "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61158-6-22:2012.

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In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC/TR 61158-1:2010 NOTE Harmonized as CLC/TR 61158-1:2010 (not modified).

Annex ZA
(normative)**Normative references to international publications
with their corresponding European publications**

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

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

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60559	-	Binary floating-point arithmetic for microprocessor systems	HD 592 S1	-
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IEC 61158-4-22	2010	Industrial communication networks - Fieldbus specifications - Part 4-22: Data-link layer protocol specification - Type 22 elements	EN 61158-4-22	2012
IEC 61158-5-22	2010	Industrial communication networks - Fieldbus specifications - Part 5-22: Application layer service definition - Type 22 elements	EN 61158-5-22	2012
ISO/IEC 7498-1	-	Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model	-	-
ISO/IEC 8802-3	-	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 8822	-	Information technology - Open Systems Interconnection - Presentation service definition	-	-
ISO/IEC 8824-1	-	Information technology - Abstract Syntax Notation One (ASN.1): Specification of basic notation	-	-
ISO/IEC 9545	-	Information technology - Open Systems Interconnection - Application Layer structure	-	-
ISO/IEC 10731	-	Information technology - Open Systems Interconnection - Basic reference model - Conventions for the definition of OSI services	-	-

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INTRODUCTION

This part of IEC 61158 is one of a series produced to facilitate the interconnection of automation system components. It is related to other standards in the set as defined by the “three-layer” fieldbus reference model described in IEC/TR 61158-1.

The application protocol provides the application service by making use of the services available from the data-link or other immediately lower layer. The primary aim of this standard is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer application entities (AEs) at the time of communication. These rules for communication are intended to provide a sound basis for development in order to serve a variety of purposes:

- as a guide for implementors and designers;
- for use in the testing and procurement of equipment;
- as part of an agreement for the admittance of systems into the open systems environment;
- as a refinement to the understanding of time-critical communications within OSI.

This standard is concerned, in particular, with the communication and interworking of sensors, effectors and other automation devices. By using this standard together with other standards positioned within the OSI or fieldbus reference models, otherwise incompatible systems may work together in any combination.

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 6-22: Application layer protocol specification – Type 22 elements

1 Scope

1.1 General

The Fieldbus Application Layer (FAL) provides user programs with a means to access the fieldbus communication environment. In this respect, the FAL can be viewed as a “window between corresponding application programs.”

This standard provides common elements for basic time-critical and non-time-critical messaging communications between application programs in an automation environment and material specific to Type 22 fieldbus. The term “time-critical” is used to represent the presence of a time-window, within which one or more specified actions are required to be completed with some defined level of certainty. Failure to complete specified actions within the time window risks failure of the applications requesting the actions, with attendant risk to equipment, plant and possibly human life.

This standard defines in an abstract way the externally visible behavior provided by the different Types of the fieldbus Application Layer in terms of:

- a) the abstract syntax defining the application layer protocol data units conveyed between communicating application entities;
- b) the transfer syntax defining the application layer protocol data units conveyed between communicating application entities;
- c) the application context state machine defining the application service behavior visible between communicating application entities; and
- d) the application relationship state machines defining the communication behavior visible between communicating application entities.

The purpose of this standard is to define the protocol provided to:

- a) define the wire-representation of the service primitives defined in IEC 61158-5-22:2010; and
- b) define the externally visible behavior associated with their transfer.

This standard specifies the protocol of the IEC fieldbus Application Layer, in conformance with the OSI Basic Reference Model (ISO/IEC 7498) and the OSI Application Layer Structure (ISO/IEC 9545).

FAL services and protocols are provided by FAL application-entities (AE) contained within the application processes. The FAL AE is composed of a set of object-oriented Application Service Elements (ASEs) and a Layer Management Entity (LME) that manages the AE. The ASEs provide communication services that operate on a set of related application process object (APO) classes. One of the FAL ASEs is a management ASE that provides a common set of services for the management of the instances of FAL classes.

Although these services specify, from the perspective of applications, how request and responses are issued and delivered, they do not include a specification of what the requesting and responding applications are to do with them. That is, the behavioral aspects of the

applications are not specified; only a definition of what requests and responses they can send/receive is specified. This permits greater flexibility to the FAL users in standardizing such object behavior. In addition to these services, some supporting services are also defined in this standard to provide access to the FAL to control certain aspects of its operation.

1.2 Specifications

The principal objective of this standard is to specify the syntax and behavior of the application layer protocol that conveys the application layer services defined in IEC 61158-5-22:2010.

A secondary objective is to provide migration paths from previously-existing industrial communications protocols. It is this latter objective which gives rise to the diversity of protocols standardized in subparts of IEC 61158-6.

1.3 Conformance

This standard does not specify individual implementations or products, nor does it constrain the implementations of application layer entities within industrial automation systems.

There is no conformance of equipment to the application layer service definition standard. Instead, conformance is achieved through implementation of this application layer protocol specification.

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 60559, *Binary floating-point arithmetic for microprocessor systems*

IEC 61158-3-22:2010¹, *Industrial communication networks – Fieldbus specifications – Part 3-22: Data-link layer service definition – Type 22 elements*

IEC 61158-4-22:2010¹, *Industrial communication networks – Fieldbus specifications – Part 4-22: Data-link layer protocol specification – Type 22 elements*

IEC 61158-5-22:2010¹, *Industrial communication networks – Fieldbus specifications – Part 5-22: Application layer service definition - Type 22 elements*

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

ISO/IEC 8802-3, *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 8822, *Information Technology – Open Systems Interconnection – Presentation service definition*

ISO/IEC 8824-1, *Information Technology – Abstract Syntax Notation One (ASN.1): Specification of basic notation*

¹ To be published.

ISO/IEC 9545, *Information Technology – Open Systems Interconnection – Application Layer structure*

ISO/IEC 10731, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*

3 Terms, definitions, abbreviations, symbols and conventions

For the purposes of this document, the following terms as defined in these publications apply:

3.1 Terms and definitions from other ISO/IEC standards

3.1.1 ISO/IEC 7498-1 terms

- a) application entity
- b) application process
- c) application protocol data unit
- d) application service element
- e) application entity invocation
- f) application process invocation
- g) application transaction
- h) real open system
- i) transfer syntax

3.1.2 ISO/IEC 8822 terms

- a) abstract syntax
- b) presentation context

3.1.3 ISO/IEC 9545 terms

- a) application-association
- b) application-context
- c) application context name
- d) application-entity-invocation
- e) application-entity-type
- f) application-process-invocation
- g) application-process-type
- h) application-service-element
- i) application control service element

3.1.4 ISO/IEC 8824-1 terms

- a) object identifier
- b) type

3.2 Fieldbus application-layer specific definitions

3.2.1

acyclic data

data which is transferred from time to time for dedicated purposes

3.2.2

bit

unit of information consisting of a 1 or a 0. This is the smallest data unit that can be transmitted

3.2.3

cell

synonym for a single DL-segment which uses RTFL communication model

3.2.4

channel

path provided for conveying data

3.2.5

client

object which uses the services of a server by initiating a message to perform a task

3.2.6

communication cycle

fixed time period between which the root device issues empty frames for cyclic communication initiation in which data is transmitted utilizing CDC and MSC

3.2.7

connection

logical binding between two application objects

3.2.8

cycle time

duration of a communication cycle

3.2.9

cyclic

events which repeat in a regular and repetitive manner

3.2.10

cyclic communication

periodic exchange of telegrams

3.2.11

cyclic data

data which is transferred in a regular and repetitive manner for dedicated purposes

3.2.12

cyclic data channel

CDC

part of one or more frames, which is reserved for cyclic data

3.2.13

data

generic term used to refer to any information carried over a fieldbus

3.2.14

device

physical entity connected to the fieldbus

3.2.15

error

discrepancy between a computed, observed or measured value or condition and the specified or theoretically correct value or condition

3.2.16

error code

identification number of a specific type of error

3.2.17

gateway

device acting as a linking element between different protocols

3.2.18

index

position of an object within the object dictionary

3.2.19

inter-cell communication

communication between a RTFL device and a RTFN device or communication between a RTFL device and another RTFL device in different cells linked by RTFN

3.2.20

interface

shared boundary between two functional units, defined by functional characteristics, signal characteristic, or other characteristics as appropriate

3.2.21

intra-cell communication

communication between a RTFL device and another RTFL device in the same cell

3.2.22

logical double line

sequence of root device and all ordinary devices processing the communication frame in forward and backward direction

3.2.23

mapping parameters

set of values defining the correspondence between application objects and process data objects

3.2.24

master clock

global time base for the PCS mechanism

3.2.25

message

ordered sequence of octets intended to convey data

3.2.26

message channel

MSC

part of one or more frames, which is reserved for acyclic data

3.2.27

network

set of devices connected by some type of communication medium, including any intervening repeaters, bridges, routers and lower-layer gateways

3.2.28

ordinary device

OD

slave in the communication system, which utilizes RTFL for cyclic and acyclic data interchange with other ODs in the same logical double line

3.2.29

precise clock synchronization

PCS

mechanism to synchronize clocks of RTFL devices and maintain a global time base

3.2.30

process data

data designated to be transferred cyclically or acyclically for the purpose of processing

3.2.31

process data object

dedicated data object(s) designated to be transferred cyclically or acyclically for the purpose of processing

3.2.32

protocol

convention about the data formats, time sequences, and error correction in the data exchange of communication systems

3.2.33

root device

RD

master in the communication system, which organises, initiates and controls the RTFL cyclic and acyclic data interchange for one logical double line

3.2.34

real time frame line

RTFL

communication model communicating in a logical double line

3.2.35

real time frame network

RTFN

communication model communicating in a switched network

3.2.36

round trip time

transmission time needed by a DLPDU from the RD to the last OD in forward and backward direction

3.2.37

sub-index

sub-position of an individual element of an object within the object dictionary

3.2.38

timing signal

time-based indication of the occurrence of an event, commonly as an interrupt signal, used for DL-user synchronization

3.2.39
topology

physical network architecture with respect to the connection between the stations of the communication system

3.3 Abbreviations and symbols

AE	Application entity
AL	Application layer
AP	Application process
APDU	Application layer protocol data unit
APO	Application process object
AR	Application relationship
AREP	Application relationship end point
ASE	Application service element
CDC	Cyclic data channel
CL	Communication layer
Cnf	Confirmation
DA	Device address or destination address
DHCP	Dynamic Host Configuration Protocol
DL-	Data-link layer (as a prefix)
DLL	DL-layer
DLPDU	DL-protocol data unit
EDS	Electronic data sheet
EMCY	Emergency
FAL	Fieldbus application layer
FCS	Frame check sequence
ID	Identification
Ind	Indication
IP	Internet protocol
IPv4	IP version 4

IPv6	IP version 6
IRQ	Interrupt request
LME	Layer management entity
MAC	Medium access control
MII	Media independent interface
MSC-MTP	Message channel message transfer protocol
MSC	Message channel
OD	Ordinary device
OS	Operating system
OSI	Open systems interconnection
PCS	Precise clock synchronization
PDO	Process data object
PID	Packet ID
PTPMSU	Point-to-multipoint network-scheduled unconfirmed
PTPNSC	Point-to-point network-scheduled confirmed
PTPNSU	Point-to-point network-scheduled unconfirmed
PTPUTC	Point-to-point user-triggered confirmed
RD	Root device
Req	Request
Rsp	Response
RTF	Real time frame
RTFL	Real time frame line
RTFN	Real time frame network
RO	Read only
RW	Read and write access
Rx	Receive direction

RxPDO	Receive PDO
SA	Source address
SDO	Service data object
SEF	Standard ISO/IEC 8802-3 Ethernet DLPDU
StdErr	Standard error output
StdIn	Standard input
StdOut	Standard output
SYNC	Synchronization
TCP	Transmission control protocol
TT	Transmission type
Tx	Transmit direction
TxPDO	Transmit PDO
UDP	User datagram protocol
WO	Write only

3.4 Conventions

3.4.1 General concept

The FAL is defined as a set of object-oriented ASEs. Each ASE is specified in a separate clause. Each ASE specification is composed of three parts: its class definitions, its services, and its protocol specification. The first two are contained in IEC 61158-5-22:2010. The protocol specification for each of the ASEs is defined in this standard.

The class definitions define the attributes of the classes supported by each ASE. The attributes are accessible from instances of the class using the Management ASE services specified in IEC 61158-5-22:2010. The service specification defines the services that are provided by the ASE.

This standard uses the descriptive conventions given in ISO/IEC 10731.

3.4.2 Abstract syntax conventions

The AL syntax elements related to PDU structure are described as shown in Table 1.

- Frame part denotes the element that will be replaced by this reproduction.
- Data field is the name of the elements.
- Data type denotes the type of the terminal symbol.
- Value/description contains the constant value or the meaning of the parameter.

Table 1 – PDU element definition

Frame part	Data field	Data type	Value/description

The attributes of an object of the object dictionary are described in a form as shown in Table 2.

- Index describes the position within the object dictionary of an object.
- Sub-index describes a single element of the object.
- Name denotes a name string for this attribute.
- Object type denotes the characterizing type for each object as specified in Table 7.
- Data type denotes the data type of this element.
- Category indicates whether the element is mandatory (M), optional (O) or depends upon setting of other attributes (C).
- Access attribute shows the access right to this element. RO means read access right, RW means read and write access right, while WO means write access right.
- PDO mapping denotes the possibility to map this attribute to TxPDO or RxPDO or to indicate that this parameter is not mappable.
- Value range contains the value range of a dedicated element or 'No' for no pre-defined value range.
- Value contains the constant value(s) and/or the meaning of the parameter or 'No' for no pre-defined value.

Table 2 – Object definition

Attribute	Value
Index	
Sub-index	
Name	
Object type	
Data type	
Category	
Access attribute	
PDO mapping	
Value range	
Value	

4 Application layer protocol specification

4.1 Operating principle

Type 22 consists of two types of communication models: RTFL and RTFN. RTFL is used to ensure synchronized cyclic real-time communication. RTFN is used to network several RTFL cells to an overall system providing data interchange between several RTFL cells and between RTFL cells and RTFN devices.

In this context, a RTFL cell describes a cell which uses RTFL for communication. An RTFL cell consists of a root device (RD) and one or several ordinary devices (OD). The central

RTFL cell element is the root device which organizes and controls RTFL cell sequences such as cyclic real-time frame sending. A RTFL RD has at least one connection to RTFL, and can include a gateway (GW) which additionally has connection to RTFN. As each OD in the RTFL cell can only have a RTFL connection, the RD incorporating a GW therefore operates as a link between RTFL and RTFN. RTFN communication is not coordinated like communication in RTFL, but utilized by a switched fully duplex ISO/IEC 8802-3 network. Thus, no determinism can be guaranteed for RTFN data transfer.

Communication of process and service data is accommodated by Type 22 networks using different mechanisms (channels) in RTFL and RTFN. Cyclic data can be transferred over the cyclic data channel (CDC). The message channel (MSC) allows additional acyclic data communication and is used for service data exchange.

Service data is typically transferred acyclic and is used for transfer of parameters, control commands, status and diagnostic data as well as for generally larger data segments. Service data are transferred either event driven or user driven (acyclic character). Parameter data used in particular in device configuration do not require strict time conditions whereas diagnostic data may have much greater time requirements.

In contrast, process data is typically transferred cyclically with different cycle times and higher real-time requirements.

Type 22 AL supports a variety of services and protocols to meet these differing requirements. Both communication models support the same fieldbus application layer. The services and protocols are mapped to the corresponding DL-services.

4.2 Device reference models

4.2.1 RTFL device reference model

Type 22 services are described using the principles, methodology and model of ISO/IEC 7498-1 (OSI). The OSI model provides a layered approach to communications standards, whereby the layers can be developed and modified independently. The Type 22 specification defines functionality from top to bottom of a full OSI model. Functions of the intermediate OSI layers, layers 3 to 6, are consolidated into either the Type 22 data-link layer or the Type 22 application layer. The device reference model for a Type 22 RTFL device is shown in Figure 1.

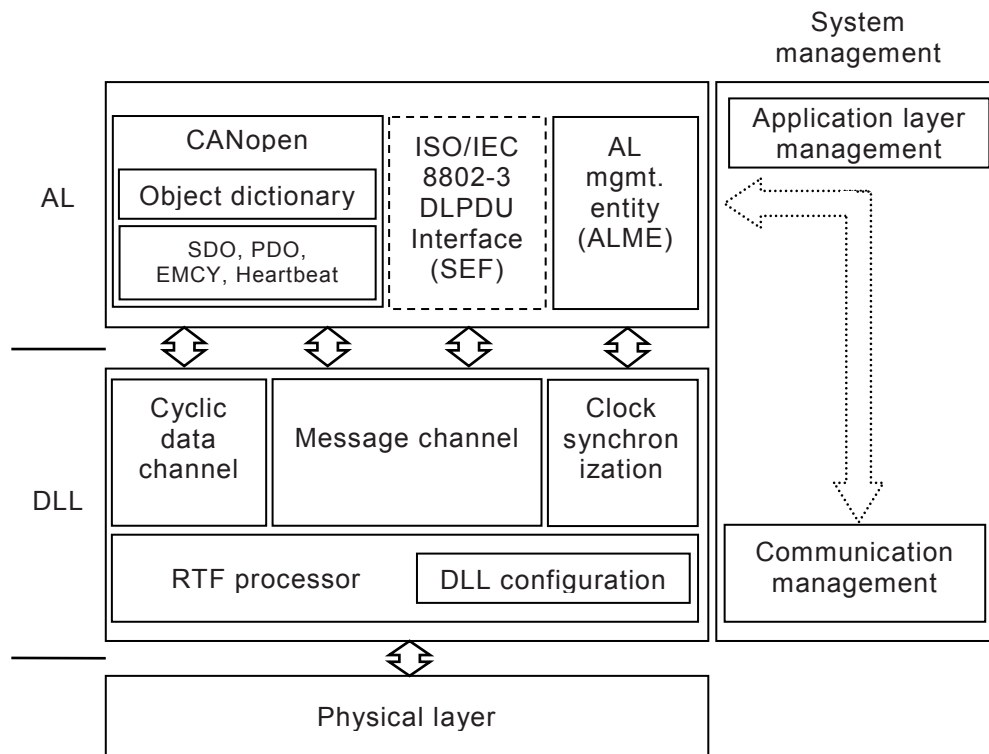


Figure 1 – RTFL device reference model

4.2.2 RTFN device reference model

Type 22 services are described using the principles, methodology and model of ISO/IEC 7498-1 (OSI). The OSI model provides a layered approach to communications standards, whereby the layers can be developed and modified independently. The Type 22 specification defines functionality from top to bottom of a full OSI model. Functions of the intermediate OSI layers, layers 3 to 6, are consolidated into either the Type 22 data-link layer or the Type 22 application layer. The device reference model for a Type 22 RTFN device is shown in Figure 2.

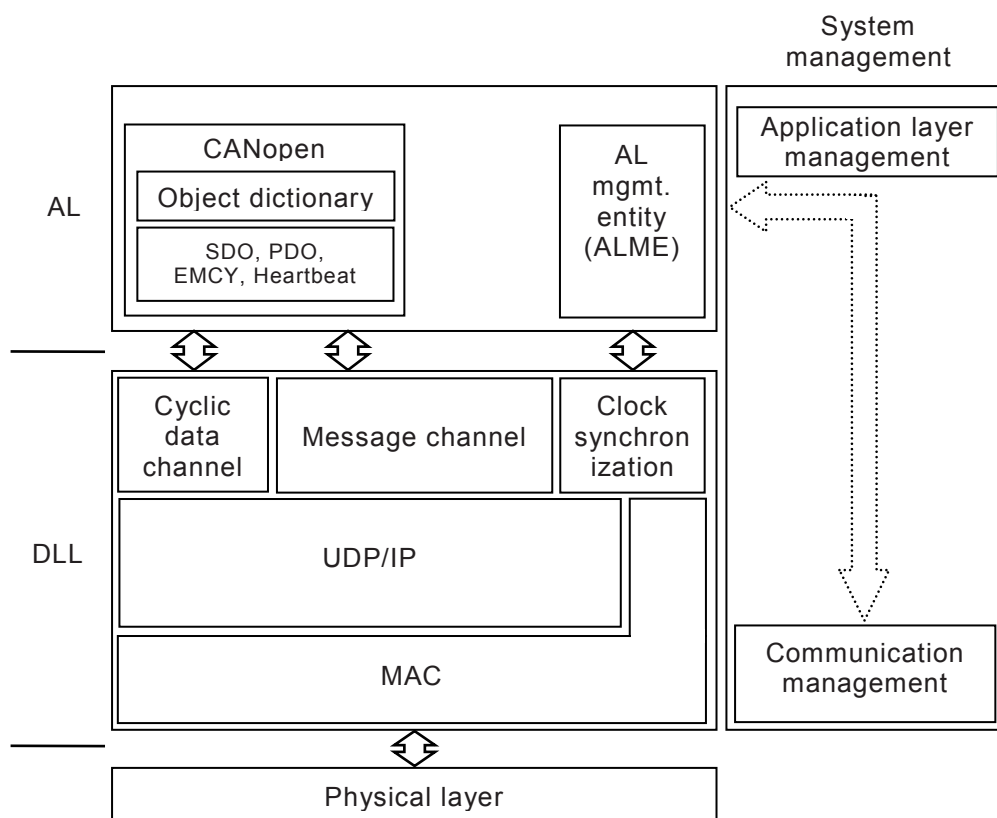


Figure 2 – RTFN device reference model

4.3 Application layer structure

The application layer consists of the following elements.

- A mandatory unit for real time data processing (CeS).
- An optional entity to enable Standard ISO/IEC 8802-3 Ethernet DLPDU communication.
- A mandatory management entity for system management.

The Application Layer uses the services provided by the Type 22 DLL to convey the AL-service data.

5 FAL syntax description

5.1 Introduction and coding principles

The abstract syntax and the transfer syntax are merged into a fixed format that is defined in the following clauses.

5.2 Data type encoding

5.2.1 Overview

To be able to exchange meaningful data across a Type 22 network, the format of this data and its meaning have to be known by communicating entities. This specification models this by the concept of data types.

The encoding rules define the representation of values of data types and the transfer syntax for the representation. Values are represented as bit sequences. Bit sequences are

transferred in sequences of octets. For numerical data types the encoding is little endian style.

The data types and encoding rules shall be valid for the AL services and protocols. The encoding rules for the ISO/IEC 8802-3. DLPDUs are specified in ISO/IEC 8802-3. The DLSDU of ISO/IEC 8802-3 DLPDUs is an octet string. The transmission order within octets depends upon MAC and PhL encoding rules.

5.2.2 Transfer syntax for bit sequences

For transmission across Type 22 AL a bit sequence is reordered into a sequence of octets. Let $b = b_{n-1}$ to b_0 be a bit sequence. Denote k a non-negative integer such that $8(k - 1) < n < 8k$. Then b is transferred in k octets assembled as shown in Table 3. The bits b_i , $i > n$ of the highest numbered octet are do not care bits.

Octet 1 is transmitted first and octet k is transmitted last. Hence the bit sequence is transferred as follows across the network:

$b_7, b_6, \dots, b_0, b_{15}, \dots, b_8, \dots$

Table 3 – Transfer syntax for bit sequences

Octet number	1.	2.	k.
—	$b_7 \dots b_0$	$b_{15} \dots b_8$	$b_{8k-1} \dots b_{8k-8}$

5.2.3 Encoding of a Boolean value

- The encoding of a Boolean value shall be primitive. The Boolean value shall consist of a single octet.
- If the Boolean value is FALSE, the single octet shall be 0 (zero). If the Boolean value is TRUE, the single octet shall be 0xff.

5.2.4 TimeOfDay

- The encoding of a TimeOfDay with and without date indication value shall be primitive.
- The octets shall be equal in value to the octets in the data value, as shown in Figure 3.

Bits	7	6	5	4	3	2	1	0	Meaning
Octets									Number of milliseconds since midnight
1	0	0	0	0	2^{27}	2^{26}	2^{25}	2^{24}	
2	2^{23}	2^{22}	2^{21}	2^{20}	2^{19}	2^{18}	2^{17}	2^{16}	
3	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	
4	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
5	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	Number of days since 01.01.84 only with date indication
6	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
msb									

Figure 3 – Encoding of TimeOfDay value

5.2.5 TimeDifference

- a) The encoding of a Time Difference with and without date indication value shall be primitive.
- b) The content octets shall be equal in value to the octets in the data value, as shown in Figure 4.

Bits	7	6	5	4	3	2	1	0	Meaning
Octets									milliseconds
1	2^{31}	2^{30}	2^{29}	2^{28}	2^{27}	2^{26}	2^{25}	2^{24}	
2	2^{23}	2^{22}	2^{21}	2^{20}	2^{19}	2^{18}	2^{17}	2^{16}	
3	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	
4	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
5	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	days only with date indication
6	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
msb									

Figure 4 – Encoding of TimeDifference value

5.2.6 Encoding of floating point values

These encoding rules are applied for data types float, Float32, double and Float64 as specified in IEC 61158-5-22:2010.

- a) The encoding of a fixed-length Floating-Point value of Floating32 and Floating64 types shall be primitive, and the content octets shall consist of exactly four or eight octets, respectively.
- b) The content octets shall contain floating-point values defined in conformance with IEC 60559. The sign is encoded in bit 7 of the first octet. It is followed by the exponent starting from bit 6 of the first octet, and then the mantissa starting from bit 6 of the second octet for Floating32 or Floating64.

5.2.7 Encoding of Integer values

Data of basic data type Integer has values in the integers. The value range is from -2^{n-1} to $2^{n-1}-1$. The data is represented as bit sequences of length n . The bit sequence

$$b = b_0 \text{ to } b_{n-1}$$

is assigned the value

$$\text{Integer}(b) = b_{n-2} \times 2^{n-2} + \dots + b_1 \times 2^1 + b_0 \times 2^0 \text{ if } b_{n-1} = 0$$

and, performing two's complement arithmetic,

$$\text{Integer}(b) = -\text{Integer}(\text{^}b) - 1 \text{ if } b_{n-1} = 1$$

Note that the bit sequence starts on the left with the least significant bit.

EXAMPLE The value $-257 = 0x\text{FEFF}$ with data type Integer16 is transferred in two octets, first $0xFF$ and then $0xFE$.

The Integer data types are transferred as specified in Table 4.

Table 4 – Transfer syntax for Integer data type

Octet number	1.	2.	3.	4.	5.	6.	7.	8.
Integer8	$b_7 - b_0$	—	—	—	—	—	—	—
Integer16	$b_7 - b_0$	$b_{15} - b_8$	—	—	—	—	—	—
Integer32	$b_7 - b_0$	$b_{15} - b_8$	$b_{23} - b_{16}$	$b_{31} - b_{24}$	—	—	—	—
Integer64	$b_7 - b_0$	$b_{15} - b_8$	$b_{23} - b_{16}$	$b_{31} - b_{24}$	$b_{39} - b_{32}$	$b_{47} - b_{40}$	$b_{55} - b_{48}$	$b_{63} - b_{56}$

NOTE 1 Data types SINT and char as defined in IEC 61158-5-22:2010 corresponds to Integer8.

NOTE 2 Data types INT and short as defined in IEC 61158-5-22:2010 corresponds to Integer16.

NOTE 3 Data types DINT and long as defined in IEC 61158-5-22:2010 corresponds to Integer32.

NOTE 4 Data type LINT as defined in IEC 61158-5-22:2010 corresponds to Integer64.

5.2.8 Encoding of Unsigned Integer values

Data of basic data type Unsigned Integer has values in the non-negative integers. The value range is 0 to 2^{n-1} . The data is represented as bit sequences of length n. The bit sequence

$$b = b_0 \dots b_{n-1}$$

is assigned the value

$$\text{Unsigned}(b) = b_{n-1} \times 2^{n-1} + \dots + b_1 \times 2^1 + b_0 \times 2^0$$

The bit sequence starts on the left with the least significant octet.

EXAMPLE The value 286 = 0x11E with data type Unsigned16 is transferred in two octets, first 0x1E and then 0x01.

The unsigned data types are transferred as specified in Table 5.

Table 5 – Transfer syntax for Unsigned data type

Octet number	1.	2.	...	4.	...	8.	...	16.	...	32.
Unsigned8	$b_7 - b_0$	—	—	—	—	—	—	—	—	—
Unsigned 16	$b_7 - b_0$	$b_{15} - b_8$	—	—	—	—	—	—	—	—
Unsigned32	$b_7 - b_0$	$b_{15} - b_8$	—	$b_{31} - b_{24}$	—	—	—	—	—	—
Unsigned64	$b_7 - b_0$	$b_{15} - b_8$	—	$b_{31} - b_{24}$	—	$b_{63} - b_{56}$	—	—	—	—
Unsigned128	$b_7 - b_0$	$b_{15} - b_8$	—	$b_{31} - b_{24}$	—	$b_{63} - b_{56}$	—	$b_{127} - b_{120}$	—	—
Unsigned256	$b_7 - b_0$	$b_{15} - b_8$	—	$b_{31} - b_{24}$	—	$b_{63} - b_{56}$	—	$b_{127} - b_{120}$	—	$b_{255} - b_{248}$

NOTE 1 Data types USINT and unsigned char as defined in IEC 61158-5-22:2010 corresponds to Unsigned8.

NOTE 2 Data types UINT and WORD as defined in IEC 61158-5-22:2010 corresponds to Unsigned16.

NOTE 3 Data types UDINT and DWORD as defined in IEC 61158-5-22:2010 corresponds to Unsigned32.

NOTE 4 Data type ULINT as defined in IEC 61158-5-22:2010 corresponds to Unsigned64.

5.2.9 Encoding of an OctetString value

- a) The encoding of a variable length OctetString value shall be primitive.
- b) There is no length field; the length is encoded implicitly.
- c) The content octets shall be a sequence of octets. The leftmost string element is encoded in the first octet, followed by second octet, followed by each octet in turn up to and including the last octet as rightmost of the content octets.

5.2.10 Encoding of a VisibleString value

- a) The encoding of a variable length VisibleString value shall be primitive.
- b) There is no length field and no termination symbol; the length is encoded implicitly.
- c) The content octets shall be a sequence of octets. The leftmost string element is encoded in the first octet, followed by the second octet, followed by each octet in turn up to and including the last octet as rightmost of the content octets.

5.2.11 Encoding of an UnicodeString value

- a) The encoding of a variable length UnicodeString value shall be primitive.
- b) There is no length field; the length is encoded implicitly.
- c) The content octets shall be a sequence of unsigned integer. The leftmost string element is encoded in the first unsigned integer, followed by the second unsigned integer, followed by each unsigned integer in turn up to and including the last unsigned integer as rightmost of the content octets.

5.3 CeS encoding

5.3.1 Object dictionary

5.3.1.1 Object dictionary structure

The dictionary is structured in form of a table as indicated in Table 6.

Table 6 – Object dictionary structure

Index	Section	Sub-section	Content
0x0001 to 0x001F	Data type	Basic data types	Definition of basic data types
0x0020 to 0x003F	—	Complex data types	Definition of complex data types
0x0040 to 0x005F	—	Manufacturer specific data types	Definition of manufacturer specific data types
0x0060 to 0x007F	—	Device profile specific basic data types	Definition of device profile specific basic data types
0x0080 to 0x009F	—	Device profile specific complex data types	Definition of device profile specific complex data types
0x00A0 to 0x0FFF	Reserved	—	—
0x1000 to 0x1FFF	Communication profile	—	Definition of the parameters which are used for communication configuration and dedicated communication purposes
0x2000 to 0x5FFF	Manufacturer defined profile	—	Definition of manufacturer specific parameters
0x6000 to 0x9FFF	Standardized device profile	—	Definition of the parameters defined in a standardized device profile
0xA000 to 0xBFFF	Standardized interface profile	—	Definition of the parameters defined in standardized interface profile
0xC000 to 0xC8FF	Type 22 RTFN interface profile	—	Definition of the parameters defined in Type 22 RTFN interface profile
0xC900 to 0xFFFF	Reserved	—	—

A logical addressing scheme is used for object dictionary access. The index field describes the position within the object dictionary. Each index is further described by an 8 bit sub-index. In case of a complex entry consisting of several elements, the sub-index subdivides an entry in up to 255 elements. For complex entries, sub-index 0x00 shall indicate the number of entries. Sub-index 255 depicts a reference to the data structure of the object and is optional. For simple object dictionary entries consisting of one object the sub-index shall have the value 0x00. Figure 5 shows the addressing scheme.

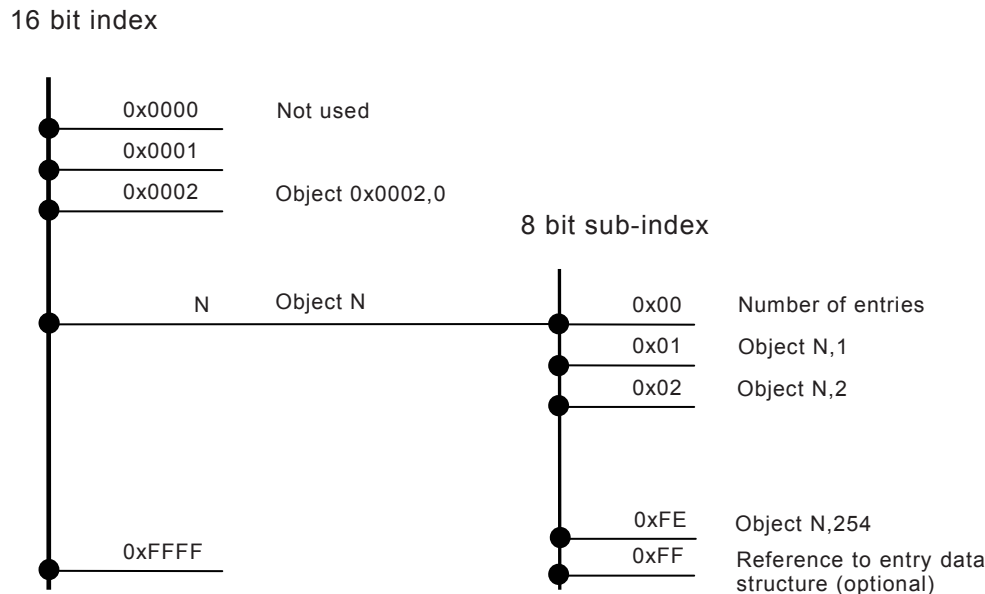


Figure 5 – Object dictionary addressing schema

5.3.1.2 Object type definitions

The index field describes the position in the object dictionary. Each single entry in the object dictionary is specified by a characterizing object type. The object type definitions are listed in Table 7.

Table 7 – Object dictionary object type definitions

Object name	Object code	Description
DOMAIN	0x0002	Indicates an entry with large variable amount of data
DEFTYPE	0x0005	Indicates a data type definition
DEFSTRUCTURE	0x0006	Indicates a record definition or definition of a structured data type
VAR	0x0007	Indicates a simple variable or a value of a simple data type
ARRAY	0x0008	Indicates a simple data type array variable
RECORD	0x0009	Indicates a record variable

5.3.1.3 Basic data type section

The basic data type section is specified in Table 8.