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Industrial communication networks – Fieldbus specifications – Part 5-21: Application layer service definition – Type 21 elements

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 5-21: Application layer service definition – Type 21 elements

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

International Standard IEC 61158-5-21 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial process measurement, control and automation.

This second edition cancels and replaces the first edition published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- added Write and Read service;
- miscellaneous editorial corrections.

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

FDIS	Report on voting
65C/947/FDIS	65C/950/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.

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

A list of all parts of the IEC 61158 series, published under the general title *Industrial communication networks – Fieldbus specifications*, can be found on the IEC web site.

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

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- withdrawn;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

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

This document 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 61158-1.

The application service is provided by the application protocol making use of the services available from the data-link or other immediately lower layer. This document defines the application service characteristics that fieldbus applications and/or system management may exploit.

Throughout the set of fieldbus standards, the term “service” refers to the abstract capability provided by one layer of the OSI Basic Reference Model to the layer immediately above. Thus, the application layer service defined in this document is a conceptual architectural service, independent of administrative and implementation divisions.

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 5-21: Application layer service definition – Type 21 elements

1 Scope

1.1 Overview

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

This part of IEC 61158 provides the common elements for basic time-critical and non-time-critical messaging communications between application programs in an automation environment as well as material specific to the Type 21 protocol. 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 International Standard defines, in an abstract way, the externally visible service provided by the FAL in terms of:

a) an abstract model for defining application resources (objects) capable of being manipulated by users *via* the FAL service;

b) the primitive actions and events of the service;

c) the parameters associated with each primitive action and event, and the form that they take;

d) the interrelationship between these actions and events, and their valid sequences.

The purpose of this document is to define the services provided to:

a) the FAL-user at the boundary between the user and the application layer of the fieldbus Reference Model;

b) systems management at the boundary between the application layer and systems management of the fieldbus Reference Model.

This document describes the structure and services of the IEC FAL, 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 (AEs) contained in 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 management of the instances of FAL classes.

Although these services specify how requests and responses are issued and delivered from the perspective of applications, they do not include a specification of what the requesting and responding applications are to do with them. That is, these services only define what requests and responses applications can send or receive, not the functions of the applications

themselves. 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 document to provide access to the FAL to control certain aspects of its operation.

1.2 Specifications

The principal objective of this document is to specify the characteristics of conceptual application layer services suitable for time-critical communications, and thus supplement the OSI Basic Reference Model in guiding the development of application layer protocols for time-critical communications.

A secondary objective is to provide migration paths from previously existing industrial communications protocols. This latter objective gives rise to the diversity of services standardized as the various types of IEC 61158, and the corresponding protocols standardized in subparts of IEC 61158-6.

This document may be used as the basis for formal application programming interfaces. Nevertheless, it is not a formal programming interface, and any such interface must address implementation issues not covered by this document, including:

a) sizes and octet ordering of various multi-octet service parameters;

b) correlation of paired primitives for request and confirmation, or indication and response.

1.3 Conformance

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

There is no conformance of equipment to this application layer service definition standard. Instead, conformance is achieved through the implementation of conforming application layer protocols that fulfill any given type of application layer services as defined in this document.

2 Normative references

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

NOTE All parts of the IEC 61158 series, as well as IEC 61784 1 and IEC 61784 2 are maintained simultaneously. Cross-references to these documents within the text therefore refer to the editions as dated in this list of normative references.

ISO/IEC/IEEE 60559:2011, *Information technology – Microprocessor Systems – Floating-Point arithmetic*

IEC 61158-3-21:2019, *Industrial communication networks – Fieldbus specifications – Part 3-21: Data-link layer service definition – Type 21 elements*

IEC 61158-4-21:2019, *Industrial communication networks – Fieldbus specifications – Part 4-21: Data-link layer protocol specification – Type 21 elements*

IEC 61158-6-21:2019, *Industrial communication networks – Fieldbus specifications – Part 6-21: Application layer protocol specification – Type 21 elements*

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

ISO/IEC 7498-3, *Information technology – Open Systems Interconnection – Basic Reference Model: Naming and addressing*

ISO/IEC 8822, *Information technology – Open Systems Interconnection – Presentation service definition*

ISO/IEC 8824 (all parts), *Information Technology – Abstract Syntax Notation One (ASN-1)*

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, symbols, abbreviations, and conventions

For the purposes of this document, the following terms, definitions, symbols, abbreviations and conventions apply.

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

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

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 8824-1 terms

For the purposes of this document, the following terms as defined in ISO/IEC 8824-1 apply:

a) object identifier
b) type

3.1.4 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

3.2 Fieldbus data link layer terms

For the purposes of this document, the following terms as defined in IEC 61158-3-21 and IEC 61158-4-21 apply.

a) DL-Time
b) DL-Scheduling-policy
c) DLCEP
d) DLC
e) DL-connection-oriented mode
f) DLPDU
g) DLSDU
h) DLSAP
i) link
j) ISO/IEC/IEEE 8802-3 MAC address
k) DL–entity identifier

3.3 Fieldbus application layer specific definitions

3.3.1
application
function or data structure for which data are consumed or produced

3.3.2
application objects
multiple object classes that manage and provide a runtime exchange of messages across the network and within the network device

3.3.3
application process
part of a distributed application on a network, which is located on one device and addressed unambiguously

3.3.4
application process object
component of an application process that is identifiable and accessible through an FAL application relationship

Note 1 to entry: Application process object definitions are composed of a set of values for the attributes of their class (see the definition for “application process object class”). Application process object definitions may be accessed remotely using the services of the FAL Object Management ASE. FAL Object Management services can

be used to load or update object definitions, to read object definitions, and to create and delete application objects and their corresponding definitions dynamically.

3.3.5
application process object class
class of application process objects defined in terms of the set of their network-accessible attributes and services

3.3.6
application relationship
cooperative association between two or more application-entity-invocations for the purpose of exchange of information and coordination of their joint operation

Note 1 to entry: This relationship is activated either by the exchange of application-protocol-data-units or as a result of preconfiguration activities.

3.3.7
application relationship application service element
application-service-element that provides the exclusive means for establishing and terminating all application relationships

3.3.8
application relationship endpoint
context and behavior of an application relationship as seen and maintained by one of the application processes involved in the application relationship

Note 1 to entry: Each application process involved in the application relationship maintains its own application relationship endpoint.

3.3.9
attribute
description of an externally visible characteristic or feature of an object

Note 1 to entry: The attributes of an object contain information about variable portions of an object. Typically, they provide status information or govern the operation of an object. Attributes may also affect the behavior of an object. Attributes are divided into class attributes and instance attributes.

3.3.10
behavior
indication of how an object responds to particular events

3.3.11
channel
single physical or logical link of an input or output application object of a server to the process

3.3.12
class
set of objects, all of which represent the same type of system component

Note 1 to entry: A class is a generalization of an object, a template for defining variables and methods. All objects in a class are identical in form and behavior, but usually contain different data in their attributes.

3.3.13
class attributes
attribute shared by all objects within the same class

3.3.14
class code
unique identifier assigned to each object class

3.3.15
class-specific service
service defined by a particular object class to perform a required function that is not performed by a common service

Note 1 to entry: A class-specific object is unique to the object class that defines it.

3.3.16
client
a) object that uses the services of another (server) object to perform a task

b) initiator of a message to which a server reacts

3.3.17
consume
act of receiving data from a producer

3.3.18
consumer
node or sink that receives data from a producer

3.3.19
consuming application
application that consumes data

3.3.20
conveyance path
unidirectional flow of APDUs across an application relationship

3.3.21
cyclic
repetitive in a regular manner

3.3.22
data consistency
means for coherent transmission and access of the input- or output-data object between and within client and server

3.3.23
device
physical hardware connected to the link

Note 1 to entry: A device may contain more than one node.

3.3.24
device profile
collection of device-dependent information and functionality providing consistency between similar devices of the same device type

3.3.25
diagnostic information
all data available at the server for maintenance purposes

3.3.26
end node
producing or consuming node

3.3.27
endpoint
one of the communicating entities involved in a connection

3.3.28
error
discrepancy between a computed, observed, or measured value or condition and the specified or theoretically correct value or condition

3.3.29
error class
general grouping for related error definitions and corresponding error codes

3.3.30
error code
identification of a specific type of error within an error class

3.3.31
event
instance of a change of conditions

3.3.32
FIFO variable
variable object class composed of a set of homogeneously typed elements, where the first written element is the first element that can be read

Note 1 to entry: In a fieldbus system, only one complete element can be transferred as a result of one service invocation.

3.3.33
frame
simplified synonym for data link protocol data unit (DLPDU)

3.3.34
group
<general> general term for a collection of objects

3.3.35
group
<addressing> when describing an address, an address that identifies more than one entity

3.3.36
invocation
act of using a service or other resource of an application process

Note 1 to entry: Each invocation represents a separate thread of control that may be described by its context. Once the service completes, or use of the resource is released, the invocation ceases to exist. For service invocations, a service that has been initiated but not yet completed is referred to as an outstanding service invocation. For service invocations, an Invoke ID may be used to identify the service invocation unambiguously and differentiate it from other outstanding service invocations.

3.3.37
index
address of an object within an application process

3.3.38
instance
actual physical occurrence of an object within a class that identifies one of many objects in the same object class

EXAMPLE California is an instance of the object class US-state.

Note 1 to entry: The terms object, instance, and object instance are used to refer to a specific instance.

3.3.39
instance attributes
attribute that is unique to an object instance and not shared by the object class

3.3.40
instantiated
object that has been created in a device

3.3.41
logical device
specific FAL class that abstracts a software component or a firmware component as an autonomous self-contained facility of an automation device

3.3.42
manufacturer ID
identification of each product manufacturer by a unique number

3.3.43
management information
network-accessible information that supports management of the operation of the fieldbus system, including the application layer

Note 1 to entry: Managing includes functions, such as controlling, monitoring, and diagnosis.

3.3.44
network
set of nodes connected by some type of communication medium, including any intervening repeaters, bridges, routers, and lower-layer gateways

3.3.45
object
abstract representation of a particular component within a device, usually a collection of related data in the form of variables, and methods (procedures) for operating on that data that have clearly defined interface and behavior

3.3.46
object dictionary
collection of definitions, communication-specific attributes and parameters, and application-dependent data

3.3.47
object-specific service
service unique to the object class that defines it

3.3.48
physical device
automation or other network device

3.3.49
point-to-point connection
connection that exists between exactly two application objects

3.3.50
pre-established AR endpoint
AR endpoint placed in an established state during configuration of the AEs that control its endpoints

3.3.51
process data
object(s) that are already pre-processed and transferred cyclically for the purpose of information or further processing

3.3.52
produce
act of sending data to be received by a consumer

3.3.53
producer
node that is responsible for sending data

3.3.54
property
general term for descriptive information about an object

3.3.55
provider
source of a data connection

3.3.56
publisher
role of an AR endpoint that transmits APDUs onto the fieldbus for consumption by one or more subscribers

Note 1 to entry: A publisher may not be aware of the identity or number of subscribers.

3.3.57
publishing manager
role of an AR endpoint in which it issues one or more confirmed service request application protocol data units (APDUs) to a publisher to request that a specified object be published. Two types of publishing managers are defined by this document, pull publishing managers and push publishing managers, each of which is defined separately.

3.3.58
push publisher
type of publisher that publishes an object in an unconfirmed service request APDU

3.3.59
push publishing manager
type of publishing manager that requests that a specified object be published using an unconfirmed service

3.3.60
push subscriber
type of subscriber that recognizes received unconfirmed service request APDUs as published object data

3.3.61
server
a) role of an application relationship endpoint (AREP) in which it returns a confirmed service response APDU to the client that initiated the request

b) object that provides services to another (client) object

3.3.62
service
operation or function than an object and/or object class performs upon request from another object and/or object class

3.3.63
station
host of one AP, identified by a unique data link connection endpoint (DLCEP)-address

3.3.64
subscriber
role of an AREP in which it receives APDUs produced by a publisher

3.4 Abbreviations and symbols

AE	Application Entity
AL	Application Layer
ALME	Application Layer Management Entity
ALP	Application Layer Protocol
APO	Application Object
AP	Application Process
APDU	Application Protocol Data Unit
AR	Application Relationship
AREP	Application Relationship End Point
ASCII	American Standard Code for Information Interchange
ASE	Application Service Element
Cnf	Confirmation
DL-	(as a prefix) Data Link -
DLCEP	Data Link Connection End Point
DLL	Data Link Layer
DLM	Data Link Management
DLSAP	Data Link Service Access Point
DLSDU	DL-service-data-unit
DNS	Domain Name Service
FAL	Fieldbus Application Layer
Ind	Indication
Req	Request
Rsp	Response

3.5 Conventions

3.5.1 Overview

The FAL is defined as a set of object-oriented ASEs. Each ASE is specified in a separate subclause. Each ASE specification is composed of two parts: its class specification and its service specification.

The class specification defines the attributes of the class. Access to these attributes is beyond the scope of this document except where specified. The service specification defines the services provided by the ASE.

3.5.2 General conventions

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

3.5.3 Conventions for class definitions

Class definitions are described using templates. Each template consists of a list of attributes for the class. The general form of the template is as shown below:

FAL ASE:			**ASE name**
CLASS:			**Class name**
CLASS ID:			**#**
PARENT CLASS:			**Parent class name**
ATTRIBUTES:			
1	(o)	Key Attribute:	numeric identifier
2	(o)	Key Attribute:	name
3	(m)	Attribute:	attribute name(values)
4	(m)	Attribute:	attribute name(values)
4.1	(s)	Attribute:	attribute name(values)
4.2	(s)	Attribute:	attribute name(values)
4.3	(s)	Attribute:	attribute name(values)
5	(c)	Constraint:	constraint expression
5.1	(m)	Attribute:	attribute name(values)
5.2	(o)	Attribute:	attribute name(values)
6	(m)	Attribute:	attribute name(values)
6.1	(s)	Attribute:	attribute name(values)
6.2	(s)	Attribute:	attribute name(values)
SERVICES:			
1	(o)	OpsService:	service name
2	(c)	Constraint:	constraint expression
2.1	(o)	OpsService:	service name
3	(m)	MgtService:	service name

(1) The FAL ASE: entry is the name of the FAL ASE that provides the services for the class being specified.

(2) The CLASS: entry is the name of the class being specified. All objects defined using this template will be an instance of this class. The class may be specified by this document, or by a user of this document.

(3) The CLASS ID: entry is a number that identifies the class being specified. This number is not used for Type 21 elements.

(4) The PARENT CLASS: entry is the name of the parent class for the class being specified. All attributes defined for the parent class and inherited by it are inherited for the class being defined, and therefore do not have to be redefined in the template for this class.

NOTE The parent-class TOP indicates that the class being defined is an initial class definition. The parent class TOP is used as a starting point from which all other classes are defined. The use of TOP is reserved for classes defined by this document.

(5) The ATTRIBUTES label indicates that the following entries are attributes defined for the class.

a) Each of the attribute entries contains a line number in column 1; a mandatory (m), optional (o), conditional (c), or selector (s) indicator in column 2; an attribute type label

in column 3; a name or a conditional expression in column 4; and an optional list of enumerated values in column 5. In the column following the list of values, the default value for the attribute may be specified.

b) Objects are normally identified by a numeric identifier or by an object name, or by both. In the class templates, these key attributes are defined under the key attribute.

c) The line number defines the sequence and the level of nesting of the line. Each nesting level is identified by period. The numbers below refer to the general template form above. Nesting is used to specify:

i) fields of a structured attribute (4.1, 4.2, 4.3);

ii) attributes conditional on a constraint statement. Attributes may be mandatory (5.1) or optional (5.2) if the constraint is true. Not all optional attributes require constraint statements as does the attribute defined in (5.2);

iii) the selection fields of a choice type attribute (6.1 and 6.2).

(6) The SERVICES label indicates that the following entries are services defined for the class.

a) An (m) in column 2 indicates that the service is mandatory for the class, while an (o) indicates that it is optional. A (c) in this column indicates that the service is conditional. When all services defined for a class are defined as optional, at least one has to be selected when an instance of the class is defined.

b) The label “OpsService” designates an operational service (1).

c) The label “MgtService” designates a management service (2).

d) The line number defines the sequence and the level of nesting of the line. Each nesting level is identified by period. Nesting within the list of services is used to specify services conditional on a constraint statement.

3.5.4 Conventions for service definitions

3.5.4.1 General

The service model, service primitives, and time-sequence diagrams used are entirely abstract descriptions; they do not represent a specification for implementation.

3.5.4.2 Service parameters

Service primitives are used to represent interactions between service user and service provider (ISO/IEC 10731). They convey parameters that indicate information available in the user/provider interaction. In any particular interface, not all parameters must be stated explicitly.

The service definition of this document uses a tabular format to describe the component parameters of the ASE service primitives. The parameters that apply to each group of service primitives are set out in tables. Each table consists of up to five columns:

a) parameter name;

b) request primitive;

c) indication primitive;

d) response primitive;

e) confirmation primitive.

One parameter, or a component, is listed in each row of each table. Under the appropriate service primitive columns, a code is used to specify the type of usage of the parameter on the primitive specified in the column:

M The parameter is mandatory for the primitive.

U The parameter is a user option, and may or may not be provided depending on dynamic usage of the service user. When not provided, a default value for the parameter is assumed.

C The parameter is conditional upon other parameters or upon the environment of the service user.

— (blank) The parameter is never present.

S The parameter is a selected item.

Some entries are further qualified by items in parentheses. These may be:

a) a parameter-specific constraint:

"(=)" indicates that the parameter is semantically equivalent to the parameter in the service primitive to its immediate left in the table;

b) an indication that some note applies to the entry:

"(n)" indicates that the following note "n" contains additional information pertaining to the parameter and its use.

3.5.4.3 Service procedures

The service procedures are defined in terms of:

- The interactions between application entities through the exchange of fieldbus APDUs;
- The interactions between an application layer service provider and an application layer service user in the same system through the invocation of application layer service primitives.

These procedures are applicable to instances of communication between systems that support time-constrained communications services within the fieldbus application layer.

4 Concepts

4.1 Common concepts

4.1.1 Overview

The fieldbus is intended to be used in factories and process plants to interconnect primary automation devices (*e.g.*, sensors, actuators, local display devices, annunciators, programmable logic controllers, small single loop controllers, and standalone field controls) with control and monitoring equipment located in control rooms.

Primary automation devices are associated with the lowest levels of the industrial automation hierarchy and perform a limited set of functions within a definite time window. Some of these functions include diagnostics, data validation, and handling of multiple inputs and outputs.

These primary automation devices, also called field devices, are located close to the process fluids, the fabricated part, the machine, the operator, and the environment. This use positions the fieldbus at the lowest levels of the computer integrated manufacturing (CIM) architecture.

Some of the expected benefits in using fieldbus systems are reductions in wiring, increases in the amount of data exchanged, a wider distribution of control between the primary automation devices and the control room equipment, and satisfaction of time-critical constraints.

Subclause 4.1 describes the fundamentals of the FAL. Detailed descriptive information about each of the FAL ASEs can be found in the overview subclause of each of the communication model specifications.