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Industrial communication networks – Fieldbus specifications – Part 3-21: Data-link layer service definition – Type 21 elements

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 3-21: Data-link 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 61158-3-21 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 Network Control Message Type;
- miscellaneous editorial corrections.

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

FDIS	Report on voting
65C/945/FDIS	65C/954/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- withdrawn;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.

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 data-link layer service defined in this document is a conceptual architectural service, independent of administrative and implementation divisions.

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 3-21: Data-link layer service definition – Type 21 elements

1 Scope

1.1 Overview

This part of IEC 61158 provides the common elements for basic time-critical messaging communications between devices in an automation environment. The term “time-critical” in this context means the prioritized full-duplex collision-free time-deterministic communication, of which one or more specified actions are required to be completed with some defined level of certainty. Failure to complete specified actions within the required time risks the 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 Type 21 data-link layer in terms of:

a) the primitive actions and events of the service;

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

c) the interrelationships between these actions and events, and their valid sequences.

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

- The Type 21 application layer at the boundary between the application and DLLs of the fieldbus reference model;
- Systems management at the boundary between the DLL and the systems management of the fieldbus reference model.

1.2 Specifications

The principal objective of this document is to specify the characteristics of conceptual DLL services suitable for time-critical communications, and to supplement the OSI Basic Reference Model in guiding the development of data link protocols for time-critical communications. A secondary objective is to provide migration paths from previously existing industrial communications protocols.

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

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

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

1.3 Conformance

This document does not specify individual implementations or products, nor do they constrain the implementations of data-link entities within industrial automation systems.

There is no conformance of equipment to this data-link layer service definition document. Instead, conformance is achieved through implementation of the corresponding data-link protocol that fulfils the Type 21 DLL services 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 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/IEEE 8802-3, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet*

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 Reference model terms and definitions

This document is based in part on the concepts developed in ISO/IEC 7498-1 and ISO/IEC 7498-3, and makes use of the following terms defined therein.

3.1.1 DL-address [ISO/IEC 7498-3]

3.1.2 DL-address-mapping [ISO/IEC 7498-1]

3.1.3 called-DL-address [ISO/IEC 7498-3]

3.1.4 calling-DL-address [ISO/IEC 7498-3]

3.1.5 centralized multi-end-point-connection [ISO/IEC 7498-1]

3.1.6 DL-connection [ISO/IEC 7498-1]

3.1.7 DL-connection-end-point [ISO/IEC 7498-1]

3.1.8 DL-connection-end-point-identifier [ISO/IEC 7498-1]

3.1.9 DL-connection-mode transmission [ISO/IEC 7498-1]

3.1.10 DL-connectionless-mode transmission [ISO/IEC 7498-1]

3.1.11 correspondent (N)-entities [ISO/IEC 7498-1]
correspondent DL-entities (N=2)
correspondent Ph-entities (N=1)

3.1.12 DL-duplex-transmission [ISO/IEC 7498-1]

3.1.13 (N)-entity [ISO/IEC 7498-1]
DL-entity (N=2)
Ph-entity (N=1)

3.1.14 DL-facility [ISO/IEC 7498-1]

3.1.15 flow control [ISO/IEC 7498-1]

3.1.16 (N)-layer [ISO/IEC 7498-1]
DL-layer (N=2)
Ph-layer (N=1)

3.1.17 layer-management [ISO/IEC 7498-1]

3.1.18 DL-local-view [ISO/IEC 7498-3]

3.1.19 DL-name [ISO/IEC 7498-3]

3.1.20 naming-(addressing)-domain [ISO/IEC 7498-3]

3.1.21 peer-entities [ISO/IEC 7498-1]

3.1.22 primitive name [ISO/IEC 7498-3]

3.1.23 DL-protocol [ISO/IEC 7498-1]

3.1.24 DL-protocol-connection-identifier [ISO/IEC 7498-1]

3.1.25 DL-protocol-data-unit [ISO/IEC 7498-1]

3.1.26 DL-relay [ISO/IEC 7498-1]

3.1.27 Reset [ISO/IEC 7498-1]

3.1.28 responding-DL-address [ISO/IEC 7498-3]

3.1.29 Routing [ISO/IEC 7498-1]

3.1.30 Segmenting [ISO/IEC 7498-1]

3.1.31 (N)-service [ISO/IEC 7498-1]
DL-service (N=2)
Ph-service (N=1)

3.1.32 (N)-service-access-point [ISO/IEC 7498-1]
DL-service-access-point (N=2)
Ph-service-access-point (N=1)

3.1.33 DL-service-access-point-address [ISO/IEC 7498-3]

3.1.34 DL-service-connection-identifier [ISO/IEC 7498-1]

3.1.35 DL-service-data-unit [ISO/IEC 7498-1]

3.1.36 DL-simplex-transmission [ISO/IEC 7498-1]

3.1.37 DL-subsystem [ISO/IEC 7498-1]

3.1.38 systems-management [ISO/IEC 7498-1]

3.1.39 DLS-user-data [ISO/IEC 7498-1]

3.2 Service convention terms and definitions

This document also makes use of the following terms defined in ISO/IEC 10731 as they apply to the data-link layer.

3.2.1 acceptor

3.2.2 asymmetrical service

3.2.3 confirm (primitive);
requestor.deliver (primitive)

3.2.4 deliver (primitive)

3.2.5 DL-confirmed-facility

3.2.6 DL-facility

3.2.7 DL-local-view

3.2.8 DL-mandatory-facility

3.2.9 DL-non-confirmed-facility

3.2.10 DL-protocol-machine

3.2.11 DL-provider-initiated-facility

3.2.12 DL-provider-optional-facility

3.2.13 DL-service-primitive;
primitive

3.2.14 DL-service-provider

3.2.15 DL-service-user

3.2.16 DLS-user-optional-facility

3.2.17 indication (primitive);
acceptor.deliver (primitive)

3.2.18 multi-peer

3.2.19 request (primitive);
requestor.submit (primitive)

3.2.20 requestor

3.2.21 response (primitive); acceptor.submit (primitive)

3.2.22 submit (primitive)

3.2.23 symmetrical service

3.3 Common data-link service terms and definitions

For the purpose of this document, the following definitions also apply.

NOTE Many definitions are common to more than one protocol Type; they are not necessarily used by all protocol Types.

3.3.1
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

[SOURCE: IEC 61918, 3.1.3]

3.3.2
DL-segment
link
local link
single data link (DL) subnetwork in which any of the connected data link entities (DLEs) may communicate directly, without any intervening data link relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the period(s) of attempted communication

3.3.3
data-link service access point
DLSAP
distinctive point at which DL-services are provided by a single DLE to a single higher-layer entity

Note 1 to entry: Definition derived from ISO/IEC 7498-1:1994, Clause 5.

3.3.4
DL(SAP) -address
either an individual DLSAP address designating a single DLSAP of a single data link service (DLS) user (DLS-user), or a group DL-address potentially designating multiple DLSAPs, each of a single DLS-user

Note 1 to entry: This terminology was chosen because ISO/IEC 7498-3 does not permit the use of the term DLSAP-address to designate more than a single DLSAP at a single DLS-user.

3.3.5
(individual) DLSAP-address
DL-address that designates only one DLSAP within the extended link

Note 1 to entry: A single DL-entity may have multiple DLSAP-addresses associated with a single DLSAP.

3.3.6
Data-link connection endpoint address
DLCEP-address
DL-address that designates either:

a) one peer DL-connection-end-point;

b) one multi-peer publisher DL-connection-end-point, and implicitly the corresponding set of subscriber DL-connection-end-points, where each DL-connection-end-point exists within a distinct DLSAP and is associated with a corresponding distinct DLSAP-address.

3.3.7
DL–entity identifier
address that designates the (single) DLE associated with a single device on a specific local link

3.3.8
device
single DLE as it appears on one local link

3.3.9
end-station
system attached to a network that is an initial source or a final destination of MAC frames transmitted across that network

Note 1 to entry: 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.

[SOURCE: IEC 61784-2, 3.1.5]

3.3.10
frame
unit of data transmission on an ISO/IEC/IEEE 8802-3 MAC (Media Access Control) that conveys a protocol data unit (PDU) between MAC service users

[SOURCE: IEEE 802.1Q-2011]

3.3.11
Frame check sequence (FCS) error
error that occurs when the computed frame check sequence value after reception of all the octets in a data link protocol data unit (DLPDU) does not match the expected residual

3.3.12
linear topology
topology where the nodes are connected in series, with two nodes connected to only one other node and all others each connected to two other nodes (that is, connected in the shape of a line)

Note 1 to entry: This topology corresponds to that of an open ring.

[SOURCE: IEC 61918, 3.1.51]

3.3.13
link
transmission path between two adjacent nodes

[SOURCE: derived from ISO/IEC 11801]

3.3.14
network management
management functions and services that perform network initialization, configuration, and error handling

3.3.15
node
network entity connected to one or more links

Note 1 to entry: A node may be either a switch, an end-station or an RTE end-station.

[SOURCE: IEC 61784-2, 3.1.17]

3.3.16
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 1 to entry: 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.

[SOURCE: IEC 61784-2, 3.1.18]

3.3.17
protocol
convention on the data formats, time sequences, and error correction for data exchange in communication systems

3.3.18
real-time
ability of a system to provide a required result in a bounded time

[SOURCE: IEC 61784-2, 3.1.19]

3.3.19
real-time communication
transfer of data in real-time

[SOURCE: IEC 61784-2, 3.1.20]

3.3.20
Real-time Ethernet
RTE
ISO/IEC/IEEE 8802-3 based network that includes real-time communication

Note 1 to entry: Other communications can be supported, providing that the real-time communication is not compromised.

Note 2 to entry: This definition is dedicated but not limited to ISO/IEC/IEEE 8802-3. It could be applicable to other IEEE 802 specifications, for example IEEE 802.11.

[SOURCE: IEC 61784-2, 3.1.21]

3.3.21
ring
active network where each node is connected in series to two other nodes

[SOURCE: IEC 61918, 3.1.71]

3.3.22
RTE end device
device with at least one RTE end-station

[SOURCE: IEC 61784-2, 3.1.26]

3.3.23
RTE end-station
end-station with RTE capability

[SOURCE: IEC 61784-2, 3.1.27]

3.4 Additional Type 21 data-link specific definitions

3.4.1
device unique identification
unique 8 octet identification to identify a Type 21 device in a network. This ID is a combination of a 6 octet ISO/IEC/IEEE 8802-3 MAC address and 2 octet DL-address

3.4.2
R-port
port in a communication device that is part of a ring structure

3.5 Common symbols and abbreviations

DL	data link (used as a prefix or adjective)
DLC	data link connection
DLCEP	data link connection endpoint
DLE	data link entity (the local active instance of the DLL)
DLL	data link layer
DLPDU	data link protocol data unit
DLPM	data link protocol machine
DLM	data link management
DLME	data link management entity (the local active instance of DLM)
DLMS	data link management service
DLS	data link service
DLSAP	data link service-access-point
DLSDU	data link service-data-unit
FIFO	first-in, first-out (queuing method)
NMT	network management
OSI	Open Systems Interconnection
Ph-	physical layer (as a prefix)
PHY	physical interface transceiver
PhL	physical layer
RTE	Real-time Ethernet
IEC	International Electrotechnical Commission
IP	Internet Protocol (see RFC 791)
ISO	International Organization for Standardization
MAC	media access control
NRT	non-real-time
PDU	protocol data unit
SAP	service access point
RT	real-time
TCP	Transmission Control Protocol (see RFC 793)
UDP	User Datagram Protocol (see RFC 768)

3.6 Additional Type 21 symbols and abbreviations

EFR	extremely fast recovery
GD	general device
LNM	line network manager
PO	power on
PnP	plug and play
RNM	ring network manager
RNMP	primary ring network manager
RNMS	secondary ring network manager
RNAC	ring network auto configuration
UID	device unique identification
Type 21 NMIB	Type 21 network management information base

3.7 Common conventions

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

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

Service primitives, used to represent service user/provider interactions (see ISO/IEC 10731), convey parameters that indicate information available in the user/provider interaction.

This document uses a tabular format to describe the component parameters of the DLS primitives. The parameters that apply to each group of DLS primitives are set out in tables throughout the remainder of this document. Each table consists of up to six columns, containing the name of the service parameter, and a column for each of those primitives and parameter-transfer directions used by the DLS, including

- the request primitive's input parameters;
- the request primitive's output parameters;
- the indication primitive's output parameters;
- the response primitive's input parameters;
- the confirmation primitive's output parameters.

NOTE The request, indication, response and confirmation primitives are also known as requestor.submit, acceptor.deliver, acceptor.submit, and requestor.deliver primitives, respectively (see ISO/IEC 10731).

One parameter, or a portion of it, is listed in each row of each table. Under the appropriate service primitive columns, a code is used to specify how the parameter is used, and its direction:

M	parameter: mandatory for the primitive;
U	parameter: a user option that may or may not be provided depending on the dynamic use of the DLS-user. When not provided, a default value for the parameter is assumed;
C	parameter is conditional upon other parameters or upon the environment of the DLS-user;
(Blank)	parameter is never present.

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

a) (=) A parameter-specific constraint indicating that the parameter is semantically equivalent to the parameter in the service primitive to its immediate left in the table;

b) (n) An indication that following note n contains additional information pertaining to the parameter and its use.

In any particular interface, not all parameters shall be stated explicitly. Some may be implicitly associated with the DLSAP at which the primitive is issued.

In the diagrams illustrating these interfaces, dashed lines indicate cause and effect or time sequence relationships, and wavy lines indicate that events occur at approximately the same time.

3.8 Additional Type 21 conventions

In the diagrams illustrating the DLS and DLM interfaces, dashed lines indicate cause and effect or time sequence relationships between actions at different stations, while solid lines with arrows indicate cause and effect time sequence relationships that occur within the DLE provider at a single station.

The following notation, a shortened form of the primitive classes defined in 3.7, is used in the figures and tables.

req request primitive

ind indication primitive

cnf confirmation primitive (confirmation)

rsp response primitive

4 Data-link layer services and concepts

4.1 General

4.1.1 Overview

This document specifies the Type 21 data link services for an ISO/IEC/IEEE 8802-3 based time-deterministic control network, which is one of the communication networks for RTE. The communication services support timing demands typical of high-performance automation applications. They do not change the basic principles of the Ethernet according to ISO/IEC/IEEE 8802-3, but extend it toward RTE. Thus, it is possible to continue to use standard Ethernet hardware, infrastructure components, or test and measurement equipment, such as network analyzers.

The Type 21 DLL provides reliable and transparent data communication between two Type 21 end devices. The Type 21 DLL also guarantees abstract transparent data transfer between DL-users so that DLL provides flexible and convenient network connectivity to network users.

4.1.2 Overview of full duplex flow control

A Type 21 device is based on an integrated switch with two ports (ring ports) connected to the ring. Therefore, a Type 21 network system is made up of full-duplex, collision-free switching devices configured as a ring or a line network. Figure 1 shows the full-duplex flow control procedure in a Type 21 network system. Type 21 guarantees collision-free data transmission between two devices linked by a full-duplex Ethernet connection so that the Type 21 DLL provides reliable, transparent, and collision-free data transmission to the DLS-users.