



BSI Standards Publication

Industrial communication networks — Fieldbus specifications

Part 4-21: Data-link layer protocol specification — Type 21 elements

National foreword

This British Standard is the UK implementation of IEC 61158-4-21:2023. It supersedes BS EN IEC 61158-4-21:2019, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/65/3, Industrial communications: process measurement and control, including fieldbus.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Date	Text affected
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Industrial communication networks - Fieldbus specifications -
Part 4-21: Data-link layer protocol specification - Type 21
elements
(IEC 61158-4-21:2023)

Réseaux de communication industriels - Spécifications des
bus de terrain - Partie 4-21: Spécification du protocole de la
couche de liaison de données - Eléments de type 21
(IEC 61158-4-21:2023)

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Protokollspezifikation des Data Link Layer
(Sicherheitsschicht) - Typ 21-Elemente
(IEC 61158-4-21:2023)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
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European foreword

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The following dates are fixed:

- latest date by which the document has to be implemented at national (dop) 2024-02-02 level by publication of an identical national standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2026-05-02 document have to be withdrawn

This document supersedes EN IEC 61158-4-21:2019 and all of its amendments and corrigenda (if any).

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The text of the International Standard IEC 61158-4-21:2023 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standard indicated:

IEC 61158-1	NOTE Approved as EN IEC 61158-1
IEC 61158-2	NOTE Approved as EN IEC 61158-2
IEC 61158-5-21	NOTE Approved as EN IEC 61158-5-21
IEC 61158-6-21	NOTE Approved as EN IEC 61158-6-21
IEC 61784-1 (series)	NOTE Approved as EN IEC 61784-1 (series)
IEC 61784-2 (series)	NOTE Approved as EN IEC 61784-2 (series)
IEC 61784-2-0:2023	NOTE Approved as EN IEC 61784-2-0:2023 (not modified)
IEC 61918:2018	NOTE Approved as EN IEC 61918:2018 (not modified) + A11:2019

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cencenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61158-3-21	2019	Industrial communication networks - Fieldbus specifications - Part 3-21: Data-link layer service definition - Type 21 elements	EN IEC 61158-3-21	2019
ISO/IEC 7498-1	1994	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	2021	Telecommunications and exchange between information technology systems - Requirements for local and metropolitan area networks - Part 3: Standard for Ethernet	-	-
ISO/IEC 10731	-	Information technology - Open Systems Interconnection - Basic Reference Model - Conventions for the definition of OSI services	-	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**INDUSTRIAL COMMUNICATION NETWORKS –
FIELDBUS SPECIFICATIONS –****Part 4-21: Data-link layer protocol specification –
Type 21 elements****FOREWORD**

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

IEC 61158-4-21 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial process measurement, control and automation. It is an International Standard.

This third edition cancels and replaces the second edition published in 2019. This edition constitutes a technical revision.

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

- a) changed Table 9, Table 15, Table 30, Table 34, Table 35, Table 43, Table 47, Table 48, Table 49, Table 58, and Table 61;
- b) changed Network Control Message Type;
- c) miscellaneous editorial corrections.

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

Draft	Report on voting
65C/1202/FDIS	65C/1243/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

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 61158-1.

The data-link protocol provides the data-link service by making use of the services available from the physical layer. The primary aim of this document is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer data-link entities (DLEs) 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:

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

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

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent. IEC takes no position concerning the evidence, validity, and scope of this patent right.

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-21: Data-link layer protocol specification – Type 21 elements

1 Scope

1.1 General

The DLL provides basic time-critical data communications between devices in an automated environment. Type 21 provides priority-based cyclic and acyclic data communication using an internal collision-free, full-duplex dual-port Ethernet switch technology. For wide application in various automation applications, Type 21 does not restrict the cyclic/acyclic scheduling policy in the DLL.

1.2 Specifications

This part of IEC 61158 describes:

- a) procedures for the timely transfer of data and control information from one data link user entity to a peer user entity, and among the data link entities forming the distributed data link service provider;
- b) procedures for giving communication opportunities based on ISO/IEC/IEEE 8802-3 MAC, with provisions for nodes to be added or removed during normal operation;
- c) structure of the fieldbus data link protocol data units (DLPDUs) used for the transfer of data and control information by the protocol of this document, and their representation as physical interface data units.

1.3 Procedures

The procedures are defined in terms of:

- a) the interactions between peer data link entities (DLEs) through the exchange of fieldbus DLPDUs;
- b) the interactions between a data link service (DLS) provider and a DLS-user in the same system through the exchange of DLS primitives;
- c) the interactions between a DLS-provider and a physical layer service provider in the same system through the exchange of Ph-service primitives.

1.4 Applicability

These procedures are applicable to instances of communication between systems that support time-critical communications services in the data link layer of the OSI or fieldbus reference models, and that require the ability to interconnect in an open systems interconnection environment. Profiles provide a simple multi-attribute means of summarizing implementation's capabilities, and thus its applicability to various time-deterministic communications needs.

1.5 Conformance

This document also specifies conformance requirements for systems implementing these procedures. This document does not contain tests to demonstrate compliance with such requirements.

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

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

ISO/IEC 7498-1:1994, *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 8802-3:2021, *Telecommunications and exchange between information technology systems – Requirements for local and metropolitan area networks – 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 and abbreviated terms

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 <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://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	called-DL-address	[ISO/IEC 7498-3]
3.1.2	calling-DL-address	[ISO/IEC 7498-3]
3.1.3	centralized multi-end-point-connection	[ISO/IEC 7498-1]
3.1.4	correspondent (<i>N</i>)-entities correspondent DL-entities (N=2) correspondent Ph-entities (N=1)	[ISO/IEC 7498-1]
3.1.5	demultiplexing	[ISO/IEC 7498-1]
3.1.6	DL-address	[ISO/IEC 7498-3]
3.1.7	DL-address-mapping	[ISO/IEC 7498-1]
3.1.8	DL-connection	[ISO/IEC 7498-1]
3.1.9	DL-connection-end-point	[ISO/IEC 7498-1]
3.1.10	DL-connection-end-point-identifier	[ISO/IEC 7498-1]
3.1.11	DL-connection-mode transmission	[ISO/IEC 7498-1]
3.1.12	DL-connectionless-mode transmission	[ISO/IEC 7498-1]
3.1.13	DL-data-sink	[ISO/IEC 7498-1]
3.1.14	DL-data-source	[ISO/IEC 7498-1]
3.1.15	DL-duplex-transmission	[ISO/IEC 7498-1]
3.1.16	DL-facility	[ISO/IEC 7498-1]
3.1.17	DL-local-view	[ISO/IEC 7498-3]
3.1.18	DL-name	[ISO/IEC 7498-3]
3.1.19	DL-protocol	[ISO/IEC 7498-1]
3.1.20	DL-protocol-connection-identifier	[ISO/IEC 7498-1]
3.1.21	DL-protocol-control-information	[ISO/IEC 7498-1]
3.1.22	DL-protocol-data-unit	[ISO/IEC 7498-1]
3.1.23	DL-protocol-version-identifier	[ISO/IEC 7498-1]
3.1.24	DL-relay	[ISO/IEC 7498-1]
3.1.25	DL-service-connection-identifier	[ISO/IEC 7498-1]
3.1.26	DL-service-data-unit	[ISO/IEC 7498-1]
3.1.27	DL-simplex-transmission	[ISO/IEC 7498-1]
3.1.28	DL-subsystem	[ISO/IEC 7498-1]
3.1.29	DL-user-data	[ISO/IEC 7498-1]
3.1.30	flow control	[ISO/IEC 7498-1]
3.1.31	layer-management	[ISO/IEC 7498-1]
3.1.32	multiplexing	[ISO/IEC 7498-3]

3.1.33	naming-(addressing)-authority	[ISO/IEC 7498-3]
3.1.34	naming-(addressing)-domain	[ISO/IEC 7498-3]
3.1.35	naming-(addressing)-subdomain	[ISO/IEC 7498-3]
3.1.36	(N)-entity DL-entity Ph-entity	[ISO/IEC 7498-1]
3.1.37	(N)-interface-data-unit DL-service-data-unit (N=2) Ph-interface-data-unit (N=1)	[ISO/IEC 7498-1]
3.1.38	(N)-layer DL-layer (N=2) Ph-layer (N=1)	[ISO/IEC 7498-1]
3.1.39	(N)-service DL-service (N=2) Ph-service (N=1)	[ISO/IEC 7498-1]
3.1.40	(N)-service-access-point DL-service-access-point (N=2) Ph-service-access-point (N=1)	[ISO/IEC 7498-1]
3.1.41	(N)-service-access-point-address DL-service-access-point-address (N=2) Ph-service-access-point-address (N=1)	[ISO/IEC 7498-1]
3.1.42	peer-entities	[ISO/IEC 7498-1]
3.1.43	Ph-interface-control-information	[ISO/IEC 7498-1]
3.1.44	Ph-interface-data	[ISO/IEC 7498-1]
3.1.45	primitive name	[ISO/IEC 7498-3]
3.1.46	reassembling	[ISO/IEC 7498-1]
3.1.47	recombining	[ISO/IEC 7498-1]
3.1.48	reset	[ISO/IEC 7498-1]
3.1.49	responding-DL-address	[ISO/IEC 7498-3]
3.1.50	routing	[ISO/IEC 7498-1]
3.1.51	segmenting	[ISO/IEC 7498-1]
3.1.52	sequencing	[ISO/IEC 7498-1]
3.1.53	splitting	[ISO/IEC 7498-1]
3.1.54	synonymous name	[ISO/IEC 7498-3]
3.1.55	systems-management	[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 terms and definitions**

For the purposes 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 61918:2018, 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 61784-2-0, 3.1.3]

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 Std 802.1Q-2018, Modified – Replaced IEEE Std 802-3 by ISO/IEC/IEEE 8802-3]

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 61918:2018, 3.1.51]

3.3.13

link

transmission path between two adjacent nodes

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 61784-2-0, 3.1.10]

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 61784-2-0, 3.1.11]

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 61784-2-0, 3.1.12]

3.3.19

real-time communication

transfer of data in real-time

[SOURCE: IEC 61784-2-0, 3.1.13]

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 Std 802.11.

[SOURCE: IEC 61784-2-0, 3.1.14]

3.3.21**ring**

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

[SOURCE: IEC 61918:2018, 3.1.71]

3.3.22**RTE end device**

device with at least one RTE end-station

[SOURCE: IEC 61784-2-0, 3.1.16]

3.3.23**RTE end-station**

end-station with RTE capability

[SOURCE: IEC 61784-2-0, 3.1.17]

3.4 Additional Type 21 definitions**3.4.1****device unique identification**

unique 8 octet identification to identify a Type 21 device in a network

Note 1 to entry: 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 IETF 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 IETF RFC 793)
UDP	User Datagram Protocol (see IETF RFC 768)

3.6 Additional Type 21 symbols and abbreviations

EFR	extremely fast recovery
GD	general device
LNМ	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

4 Overview of the data-link protocol

4.1 General

Type 21 extends Ethernet according to the ISO/IEC/IEEE 8802-3 with mechanisms to transfer data with predictable timing demands typical of high-performance automation. It does not change the basic principles of the Ethernet according to ISO/IEC/IEEE 8802-3 but extends 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.

4.2 Overview of medium access control

A Type 21 device requires an integrated switch with two ports (ring ports) connected to the ring. A Type 21 network system is constructed with full-duplex, collision-free Ethernet switching devices as a ring or a line network. Type 21 guarantees collision-free data transmission between two devices linked by a full-duplex Ethernet connection. Thus, the Type 21 data link layer provides reliable, transparent and collision-free data transmission among DLS-users.

A Type 21 connection provides collision-free, full-duplex data communication between two devices. Therefore, a Type 21 device can transmit a frame at any time without restriction of media access rights. Type 21 data link layer does not restrict the scheduling method to use for data link resources, but each device can be individually scheduled by the application program so that Type 21 can be applied flexibly in various applications.

A Type 21 frame is delivered to the destination device in one of the following two ways:

- a frame is initiated by a source device and directly transmitted to the neighboring destination device;
- a frame is initiated by a source device and forwarded to the destination device by intermediate devices.

When a frame is forwarded by the intermediate device, the frame forwarding procedure is processed by the internal hardware switch to minimize the processing time, and it does not affect the performance of Type 21 DLL.

4.3 Service assumed from the physical layer

This document describes the assumed physical layer service (PhS) and the constraints used by the DLE. The physical service is assumed to provide the following service primitives specified by ISO/IEC/IEEE 8802-3:2021, Clause 2.

The assumed primitives of PhS are MA-DATA.request and MA-DATA.indication.

The temporal relationship of the primitives is shown in Figure 1.

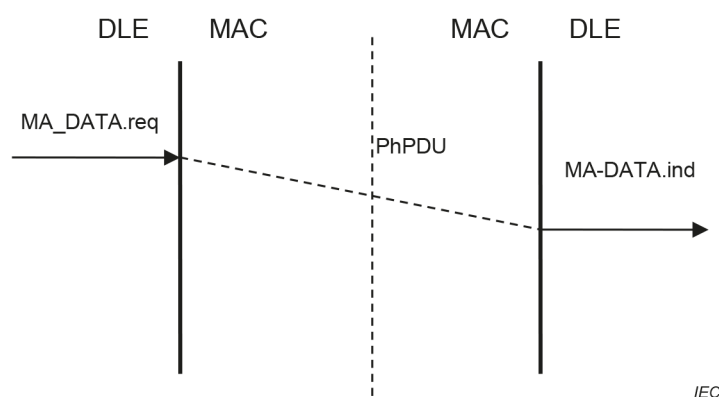


Figure 1 – Interaction of PhS primitives with DLE

The MA-DATA request primitive defines the transfer of data from a MAC client entity to a single peer entity or multiple peer entities in the case of group addresses.

The MA-DATA indication primitive defines the transfer of data from the MAC sublayer entity (through the optional MAC control sublayer, if implemented) to the MAC client entity or entities in the case of group addresses.

4.4 DLL architecture

4.4.1 General

The Type 21 DLL provides reliable and efficient higher-level data transfer service using a full-duplex ring or line topology without any specific access control scheme. The Type 21 DLL is modeled as a combination of control components of the data link protocol machine (DLPM) and the DLL management interface.

The DLPM transmits the data link service data unit (DLSDU) generated by the local DLS-user to the appropriate R-port according to the data link service policy. The DLPM also examines the received frame and delivers the received DLPDU to the appropriate DLS-user.

The DLL management interface provides DLL management functions to maintain the network management information base (NMIB). The NMIB includes local device information, network information and the path table. The DLL is comprised of the components listed in Table 1.

Table 1 – DLL components

Components	Description
DL-protocol machine (DLPM)	Transmits the DLSDU received from local DLS-user through the real-time queue (RT-queue) or non-real-time queue (NRT-queue). Examines the received frame and delivers the DLPDU to the appropriate DLS-user.
DLL management interface (DLM-interface)	Holds the station management variables that belong to the DLL, and manages synchronized changes of the link parameters.

The internal arrangement of these components, and their interfaces, are shown in Figure 2. The arrowheads illustrate the primary direction of the flow of data and control.

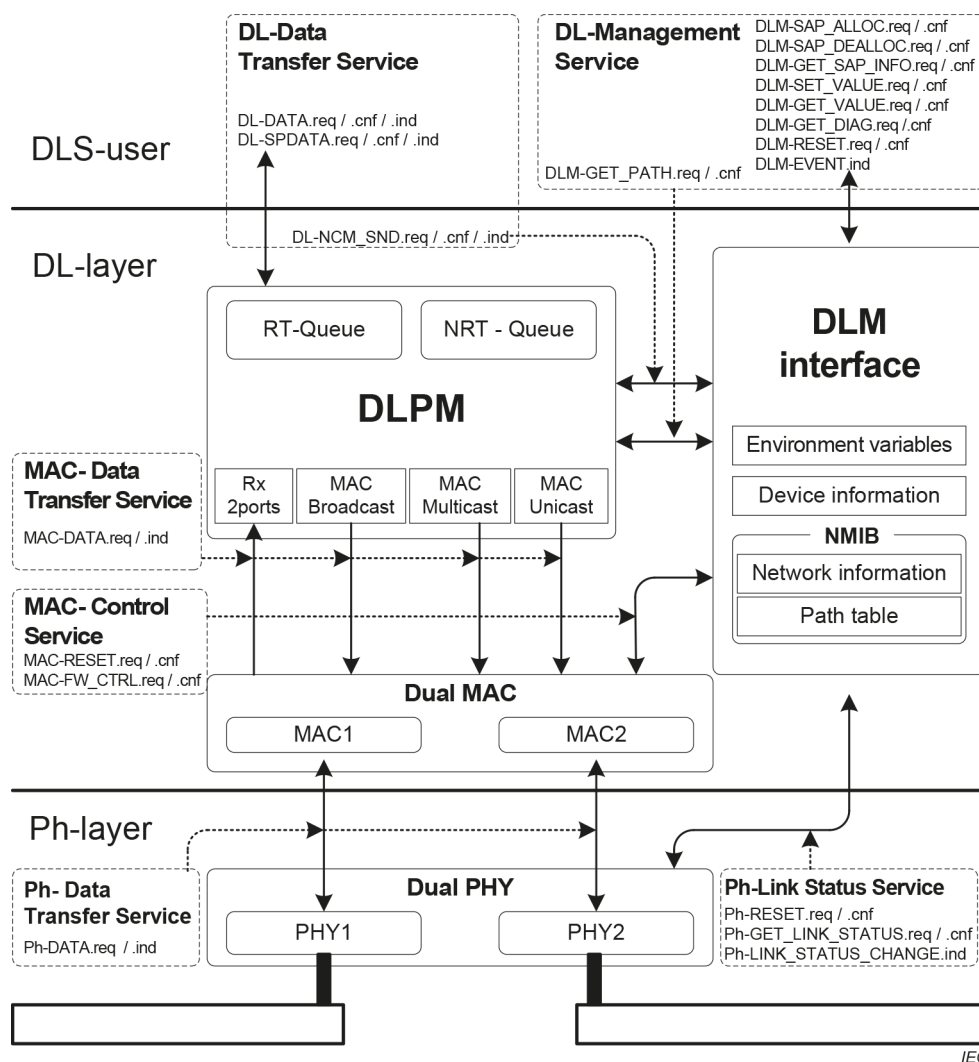


Figure 2 – Data-link layer architecture

4.4.2 DLL management (DLM) interface support function

DLM is one of the key Type 21 features that enables the Plug and Play (PnP), Network Auto Configuration (NAC), and Extremely Fast Recovery (EFR) functions. DLM spontaneously maintains and shares local device information and network-related information with every device on the network.

- Type 21 NMIB management

The DLM interface maintains the NMIB including the local device information that indicates the physical and logical status of the device, the network information that indicates the current network configuration status, and the path table that indicates the path information to the other devices and their profiles.

- Plug and Play (PnP)

When a device joins the existing network, it is automatically detected and configured without extra manual configuration of parameters so that the new device can communicate directly with the other devices on the network.

- Network Auto Configuration (NAC)

Type 21 supports ring and line network topologies. When the network is changed from ring to line or from line to ring topology, the change is automatically detected and broadcast to every device on the network, and then the network information and path table entries are automatically updated.

- Extremely Fast Recovery (EFR)
When the network is changed from ring to line topology, network information and path information are automatically updated within 10 ms.
- System diagnostic services
The DLM interface also provides system diagnostic service.

4.5 Data type

4.5.1 General

This document describes the basic Type 21 data types. The data types described in this document are only the normative references to represent Type 21 data type formats. The implementation issues are not covered in this document.

4.5.2 Boolean

Data of basic data type BOOLEAN can have the values TRUE or FALSE. The values are represented as bit sequences of length 1. The value TRUE is represented by a 1 and the value FALSE is represented by a 0.

4.5.3 Unsigned integer

Data of basic data type UNSIGNED n have values of non-negative integers. The value range is 0,..., 2^{n-1} . The data are represented as bit sequences of length n . The bit sequence

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

is assigned the value

$$\text{UNSIGNED}_n = b_0 2^0 + b_1 2^1 + \dots + b_{n-1} 2^{n-1}$$

The bit sequence starts on the right with the least significant octet as shown in Table 2.

Table 2 – UNSIGNED n data type

Octet number	1	2	3	4	5	6	7	8
UNSIGNED8	$b_0..b_7$							
UNSIGNED16	$b_0..b_7$	$b_8..b_{15}$						
UNSIGNED24	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$					
UNSIGNED32	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$	$b_{24}..b_{31}$				
UNSIGNED40	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$	$b_{24}..b_{31}$	$b_{32}..b_{39}$			
UNSIGNED48	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$	$b_{24}..b_{31}$	$b_{32}..b_{39}$	$b_{40}..b_{47}$		
UNSIGNED56	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$	$b_{24}..b_{31}$	$b_{32}..b_{39}$	$b_{40}..b_{47}$	$b_{48}..b_{55}$	
UNSIGNED64	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$	$b_{24}..b_{31}$	$b_{32}..b_{39}$	$b_{40}..b_{47}$	$b_{48}..b_{55}$	$b_{56}..b_{63}$

4.5.4 Signed integer

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

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

is assigned the value

$\text{INTEGER}_n = b_0 2^0 + b_1 2^1 + \dots + b_{n-2} 2^{n-2}$, when b_{n-1} is 0, and

$\text{INTEGER}_n = -\text{Complement}(b) - 1$, when b_{n-1} is 1.

The bit sequence starts on the right with the least significant octet as shown in Table 3.

Table 3 – INTEGER_n data type

Octet number	1	2	3	4	5	6	7	8
INTEGER8	$b_0..b_7$							
INTEGER16	$b_0..b_7$	$b_8..b_{15}$						
INTEGER24	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$					
INTEGER32	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$	$b_{24}..b_{31}$				
INTEGER40	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$	$b_{24}..b_{31}$	$b_{32}..b_{39}$			
INTEGER48	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$	$b_{24}..b_{31}$	$b_{32}..b_{39}$	$b_{40}..b_{47}$		
INTEGER56	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$	$b_{24}..b_{31}$	$b_{32}..b_{39}$	$b_{40}..b_{47}$	$b_{48}..b_{55}$	
INTEGER64	$b_0..b_7$	$b_8..b_{15}$	$b_{16}..b_{23}$	$b_{24}..b_{31}$	$b_{32}..b_{39}$	$b_{40}..b_{47}$	$b_{48}..b_{55}$	$b_{56}..b_{63}$

4.5.5 Octet String

The data type OCTET_STRING_n is defined below. The *n* represents the octet length of the octet string.

ARRAY[*n*] of UNSIGNED8 OCTET_STRING_n

4.5.6 Visible String

The data type VISIBLE_STRING_n is defined below. The admissible values of data of type VISIBLE_CHAR are 0x00 and the range 0x20–0x7E. The data are interpreted as 7-bit coded characters. The *n* indicates the octet length of the visible string.

UNSIGNED8 VISIBLE_CHAR

ARRAY[*n*] of VISIBLE_CHAR VISIBLE_STRING_n

There is no 0x00 necessary to terminate the string.

4.5.7 Time of day

The data type TIMEOFDAY is defined below. TIMEOFDAY consists of UNSIGNED16 date counting and UNSIGNED32 millisecond fields.

TIMEOFDAY

UNSIGNED32 milliseconds: the count from time 00:00 in milliseconds.

UNSIGNED16 date count: the number of days from 1984–01–01.

4.6 Local parameters and variables

4.6.1 General

This document uses DLS-user request parameters $P(\dots)$ and local variables $V(\dots)$ as a means of clarifying the effects of certain actions and the conditions under which those actions are valid. This document also uses local timers $T(\dots)$ as a means of monitoring the actions of the distributed DLS-provider and of ensuring a local DLE response to the absence of those actions. This document uses local counters $C(\dots)$ for performing rate measurement functions. It also uses local queues $Q(\dots)$ as a means of ordering certain activities, of clarifying the effects of certain actions, and of clarifying the conditions under which those activities are valid.

Unless otherwise specified, at the moment of their creation or of DLE activation:

- a) all variables shall be initialized to their default value, or to their minimum permitted value if no default is specified;
- b) all counters shall be initialized to zero;
- c) all timers shall be initialized to inactive.

DLM can change the values of configuration variables.

Local parameters and variables include DLE configuration parameters, local device information, and NMIB variables. The DLE operational condition is stored in DLE configuration parameters and the DLE configuration parameters are configured locally or remotely according to the application. Local data link information, such as DL-entity identifier and the status of each R-port, are stored in the local device information. NMIB includes network information and the path table. Network topology and the network-related variables are stored in the network information, and the device profile and path information of the other devices on the network are summarized in the path table.

4.6.2 DLE configuration parameters

4.6.2.1 General

These parameters are required to configure the local DLE operation, and they are managed by DLM. Every device on the same network segment has the same DLE configuration parameters. DLM-GET_VALUE service and DLM-SET_VALUE service are used to read or write the DLE configuration parameters. Table 4 shows the list of DLE configuration parameters.

Table 4 – DLE configuration parameters

Parameter	Data type	Default value	Description
Max DL-entity identifier	UNSIGNED16	255	Maximum DL-entity identifier 256 to 65 535: reserved
DLPM scheduling policy	UNSIGNED8	0	0: First-In, First-Out 1: Fixed priority 2: to 255: reserved

4.6.2.2 $P(\text{MAX_ADDR})$: Maximum DL-entity identifier

This variable holds the maximum device address and is set by the DLM. The range of this variable is 1 to 255. The default value of this variable is 255. This variable also indicates the maximum number of path table entries in the NMIB. The values in the range 256 to 65 535 are reserved.

4.6.2.3 P(DLPMSP): data link protocol machine scheduling policy

This variable holds the scheduling policy of the local DLPM, which dictates how to serve the concurrent DLSDUs in the RT-queue. The NRT-queue is not scheduled by the DLPMSP. DLPMSP can have one of the following values:

- a) 0: first-in, first-out. The first received frame is served first. In this case, the message priority in the DLSDU is ignored;
- b) 1: Fixed priority. The DLSDU with high priority is served first. If many DLSDUs are stacked with the same priority, the frame received first is served first;
- c) 2 to 255: reserved.

4.6.3 Queues to support data transfer

4.6.3.1 General

When a DLS-user generates a DLSDU to be transmitted by the DLPM, the DLSDU is encapsulated by the DLPDU. The DLPDU is then stored in the RT-queue or the NRT-queue according to its application and service type. Table 5 shows the queue list for Type 21 data transfer.

Table 5 – Queues to support data transfer

Parameter	Data type	Default value	Description
RT-queue	—	—	Transmit queue to store the real-time data
NRT-queue	—	—	Transmit queue to store the non-real-time data

4.6.3.2 Q(RTQ): RT-queue

The RT-queue stores the real-time DLPDUs generated by a DLS-user to be transmitted by the DLPM. The size of the RT-queue is not restricted in this document and it is considered a detail of the local implementation. The RT-queue is scheduled by the DLPM.

4.6.3.3 Q(NRTQ): NRT-queue

The NRT-queue stores non-real-time DLPDUs generated by a DLS-user. The size of the NRT-queue is not restricted in this document and it is considered a detail of the local implementation. Messages in the RT-queue are transmitted first. Messages in the NRT-queue are transmitted only when the RT-queue is empty.

4.6.4 Variables to support SAP management

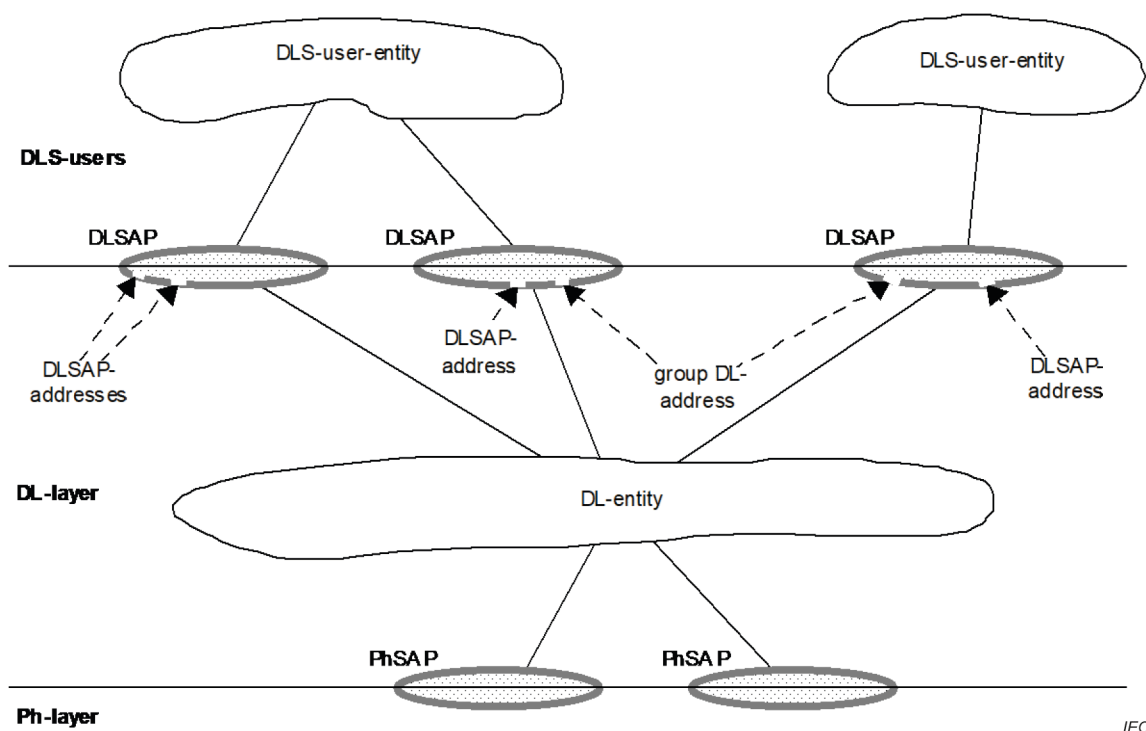
4.6.4.1 General

Allocation and de-allocation of the data link service access point (DLSAP) is managed by the DLM. When a frame is received, the DLPM examines the destination service access point (DSAP) in the DLSDU. If the DSAP is already allocated to a DLS-user, the DLM returns the appropriate DLS-user ID equivalent for the received DSAP address, and the DLPM delivers the received DLSDU to the DLS-user. If the service access point (SAP) is not allocated and no appropriate DLS-user ID is found in the DLM, the received DLSDU is discarded by the DLPM. Therefore, to receive a DLSDU from a certain peer DLS-user, a DLS-user shall first obtain a SAP allocation using the DLM-SAP_ALLOC service. Once the SAP is allocated to a DLS-user, it is used to send and receive data until the SAP is deallocated and returned to the DLM. The deallocated SAP can be used again after reallocation. The SAP address and its appropriate DLS-user ID are stored together and maintained by the DLM. The maximum number of SAP management items is 65 535 but the method to allocate and de-allocate the SAP address is not restricted in this document. Table 6 shows the list of SAP management variables.

Table 6 – Variables to support SAP management

Parameter	Data type	Default value	Description
SAP	UNSIGNED16	—	Service access point
DLS-user ID	UNSIGNED32	—	Numeric identification of the DLS-user that owns the SAP allocation

NOTE The definition of DLSAP, derived from ISO/IEC 7498-1, is explained here to facilitate understanding of the critical distinction between DLSAPs and their DL-addresses (see Figure 3).



IEC

NOTE 1 DLSAPs and physical layer service access points (PhSAPs) are depicted as ovals spanning the boundary between two adjacent layers.

NOTE 2 DL-addresses are depicted as designating small gaps (points of access) in the DLL portion of a DLSAP.

Figure 3 – Relationships of DLSAPs, DLSAP-addresses, and group DL-addresses

A single DLE can have multiple DLSAP-addresses and group DL-addresses associated with a single DLSAP.

4.6.4.2 V(SAP): SAP

This variable holds the SAP. The value for this variable is in the range 0 to 65 535.

4.6.4.3 V(DLS_USER_ID): DLS-user ID

This variable holds the 4-octet numeric identification of the DLS-user who owns the SAP allocation.

4.6.5 Variables to support local device information management

4.6.5.1 General

To maintain the network topology, every device manages a device database including the local device information and the other device information. Table 7 shows the list of device information management variables.

Table 7 – Variables to support device information management

Parameter	Data type	Default value	Description
DL–entity identifier	UNSIGNED16	INVALID_ADDR	Local DL–entity identifier
Device flags	UNSIGNED16	0	Local device flags
Device type	UNSIGNED16	0	Local device type
Hop count	UNSIGNED16	0	Hop count
Device UID	UNSIGNED64	INVALID_UID	Local device unique ID
Device UID for R-port1	UNSIGNED64	INVALID_UID	Device unique ID connected through R-port1
Device UID for R-port2	UNSIGNED64	INVALID_UID	Device unique ID connected through R-port2
MAC address	UNSIGNED48	0	Local device MAC address
Reserved0	UNSIGNED16	0	Reserved
Port information	UNSIGNED16	0	Local device port information
Device state	UNSIGNED8	0	DLM state
Protocol version	UNSIGNED8	0	Local device protocol version
Device description	VISIBLE_STRING[16]	" "	Device description string
Reserved1	UNSIGNED32	0	Reserved

4.6.5.2 V(DL_ADDR): DL–entity identifier

This variable holds the DL–entity identifier that designates the (single) DL–entity associated with a single device on a specific local link whose value is constrained to the range 0 to 255. The DL–entity identifier can be provided by hardware settings (for example, rotary switch) or set by software. The DL–entity identifier is defined in Table 8.

Table 8 – DL–entity identifier

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Read/Write	Read	0 to 255: DL–entity identifier 256 to 65 535: reserved

4.6.5.3 V(DEV_FLAG): Device Flag

This variable holds the flags for events that occurred in a local device. When the local DL–entity identifier collision flag is set, EVENT_THIS_ADDR_COLLISION event is generated by the DLM, and then the local DL–entity identifier collision flag is cleared. When the DLM state change flag is set, EVENT_DEV_STATE_CHG is generated by the DLM, and then the DLM state change flag is cleared. Type 21 device flags and event flags are listed in Table 9.

Table 9 – Device flags

Data type	Position	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Bit 0	Read/Write	Read	Collision
	Bit 1	Read/Write	Read	Changed
	Bit 2	Read/Write	Read	Frame forward enabled between R-port1 and R-port2
	Bit 3 – Bit 15	—	—	All others reserved

4.6.5.4 V(DLM_STATE): DLM state

This variable holds the DLM state. DLM state is defined as shown in Table 10.

Table 10 – DLM state

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED8	Read/Write	Read	0: INVALID_DLM_STATE 1: standalone state (SA) 2: line network manager state (LNM) 3: general Device state (GD) 4: primary ring network manager state (RNMP) 5: secondary ring network manager state (RNMS) 6 to 255: reserved

4.6.5.5 V(DEV_UID): Device UID

This variable holds the unique 8-octet identification that identifies a Type 21 device in a network. It is a combination of the 6-octet ISO/IEC/IEEE 8802-3 MAC address and the 2-octet DL-entity identifier. The Device UID is defined as shown in Table 11.

Table 11 – Device Unique Identification

Data type	Position	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED64	Bit 0 – 47	Read/Write	Read	ISO/IEC/IEEE 8802-3 MAC Address
	Bit 48 – 63	Read/Write	Read	0 to 255: DL-entity identifier 256 to 65 535: reserved

4.6.5.6 V(DEV_UID_RP1): Device UID for R-port1

This variable holds the UID of the device that is linked through the R-port1. The Device UID for R-port1 is defined as shown in Table 12.

Table 12 – Unique identification of device connected to R-port1

Data type	Position	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED64	Bit 0 – 47	Read/Write	Read	ISO/IEC/IEEE 8802-3 MAC Address
	Bit 48 – 63	Read/Write	Read	0 to 255: DL–entity identifier 256 to 65 535: reserved

4.6.5.7 V(DEV_UID_RP2): Device UID for R-port2

This variable holds the UID of the device that is linked through the R-port2. The Device UID for R-port2 is defined as shown in Table 13.

Table 13 – Unique identification of device connected to R-port2

Data type	Position	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED64	Bit 0 – 47	Read/Write	Read	ISO/IEC/IEEE 8802-3 MAC Address
	Bit 48 – 63	Read/Write	Read	0 to 255: DL–entity identifier 256 to 65 535: reserved

4.6.5.8 V(MAC_ADDR): MAC address

This variable holds 6-octet ISO/IEC/IEEE 8802-3 Ethernet MAC address of local device. As a Type 21 device has two Ethernet MAC ports, both MAC addresses should be identical. The MAC address is defined as shown in Table 14.

Table 14 – MAC address

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED48	Read/Write	Read	ISO/IEC/IEEE 8802-3 MAC Address

4.6.5.9 V(PORT_INFO): Port information

This variable holds the port information for each R-port. It is defined as shown in Table 15.

Table 15 – Port information

Data type	Position	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Bit 0	Read/Write	Read	R-port1 link down
	Bit 1	Read/Write	Read	Received NCM_FAMILY_RES message from R-port1
	Bit 2	Read/Write	Read	A NCM_FAMILY_RES message has been sent for R-port1
	Bit 3	Read/Write	Read	A NCM_ADV_THIS message has been received from neighbor node of R-port1
	Bit 4	Read/Write	Read	A NCM_MEDIA_LINKED message has been received from neighbor node of R-port1
	Bit 5 – 7	Read/Write	Read	Reserved
	Bit 8	Read/Write	Read	R-port2 link down
	Bit 9	Read/Write	Read	Received NCM_FAMILY_RES message from R-port2
	Bit 10	Read/Write	Read	A NCM_FAMILY_RES message has been sent for R-port2
	Bit 11	Read/Write	Read	A NCM_ADV_THIS message has been received from neighbor node of R-port2
	Bit 12	Read/Write	Read	A NCM_MEDIA_LINKED message has been received from neighbor node of R-port2
	Bit 13 – 15	Read/Write	Read	Reserved

4.6.5.10 V(PROTOCOL_VER): Protocol version

This variable holds the protocol version of local device. It is defined as shown in Table 16.

Table 16 – Protocol version

Data type	Position	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED8	Bit 0 – 1	Read	Read	0x00: major version 1 0x01: major version 2 0x02: major version 3 0x03: major version 4
	Bit 2 – 3	Read	Read	0x00: minor version 0 0x01: minor version 1 0x02: minor version 2 0x03: minor version 3
	Bit 4 – 7	—	—	Reserved

4.6.5.11 V(DEV_TYPE): Device type

This variable holds the local device type that represents the general function of the device. The value of this variable is defined as shown in Table 17.

Table 17 – Device type

Data type	Position	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Bit 0 – 7	Read	Read/Write	0 to 255: general device type 0: invalid device type 1: programmable logic controller (PLC) 2: motion controller 3: human-machine interface (HMI) 4: industrial personal computer 5: inverter 6: simple I/O 7 to 255: reserved
	Bit 8 – 15	Read	Read/Write	0 to 255: application specific device type

4.6.5.12 V(DEV_DESC): Device description

This variable contains a description of the local device. The maximum length of this variable is 16 octets. It is defined as shown in Table 18.

Table 18 – Device description

Data type	Access type DLM	Access type DLS-user	Value/Description
VISIBLE_STRING[16]	—	Read/Write	Any string defined by a DLS-user set using the set DLL configuration service

4.6.5.13 V(HOP_CNT): Hop count

This variable holds the count of the number of devices between two devices. When the DLM receives NCM_ADV_THIS or NCM_LA DLPDU, the DLM saves the received hop count value in this variable, then increments the hop counts in the received frame by 1 and transmits the frame through the other R-port. In this way, each device builds its own path table with a hop count for R-port1 and a hop count for R-port2. This variable is defined as shown in Table 19.

Table 19 – Hop count

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Read/Write	—	0 to 255: Hop count 256 to 65 535: reserved

4.6.6 Variables and counter to support network information management**4.6.6.1 General**

Network information is managed automatically by the DLM. Network information variables and counters are summarized in Table 20.