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BSI Standards Publication

Industrial communication networks — Fieldbus specifications

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

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National foreword

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

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

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English version

**Industrial communication networks -
Fieldbus specifications -
Part 4-21: Data-link layer protocol specification -
Type 21 elements
(IEC 61158-4-21:2010)**

Réseaux de communication industriels -
Spécifications des bus de terrain -
Partie 4-21: Spécification du protocole de
la couche de liaison de données -
Éléments de Type 21
(CEI 61158-4-21:2010)

Industrielle Kommunikationsnetze -
Feldbusse -
Teil 4-21: Protokollspezifikation des Data
Link Layer (Sicherungsschicht) -
Typ 21-Elemente
(IEC 61158-4-21:2010)

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Foreword

The text of document 65C/605/FDIS, future edition 1 of IEC 61158-4-21, prepared by SC 65C, "Industrial networks", of IEC/TC 65, "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61158-4-21:2012.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2012-12-28
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-03-28

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 61158-4-21:2010 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 standards indicated:

IEC/TR 61158-1:2010	NOTE Harmonized as CLC/TR 61158-1:2010 (not modified).
IEC 61158-2:2010	NOTE Harmonized as EN 61158-2:2010 (not modified).
IEC 61158-5-21:2010	NOTE Harmonized as EN 61158-5-21:2012 (not modified).
IEC 61158-6-21:2010	NOTE Harmonized as EN 61158-6-21:2012 (not modified).

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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

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

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61158-3-21	2010	Industrial communication networks - Fieldbus specifications - Part 3-21: Data-link layer service definition - Type 21 elements	EN 61158-3-21	2012
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 8802-3	2000	Information technology - Telecommunications - and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications	-	-
ISO/IEC 10731	1994	Information technology - Open Systems Interconnection - Basic reference model - Conventions for the definition of OSI services	-	-

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INTRODUCTION

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

The data-link protocol provides the data-link service by making use of the services available from the physical layer. The primary aim of this standard is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer 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 standard is concerned, in particular, with the communication and interworking of sensors, effectors and other automation devices. By using this standard together with other standards positioned within the OSI or fieldbus reference models, otherwise incompatible systems may work together in any combination.

NOTE Use of some of the associated protocol types is restricted by their intellectual-property-right holders. In all cases, the commitment to limited release of intellectual-property-rights made by the holders of those rights permits a particular data-link layer protocol type to be used with physical layer and application layer protocols in type combinations as specified explicitly in the profile parts. Use of the various protocol types in other combinations may require permission of their respective intellectual-property-right holders.

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning Type 21 elements and possibly other types given in subclause 4.1, 4.2 and 7.3 as follows:

KR 0789444	[LS]	A communication packet processing apparatus and method for ring topology ethernet network capable of preventing permanent packet looping
KR 0732510	[LS]	Network system
KR 0870670	[LS]	Method for determining a Ring Manager Node

IEC takes no position concerning the evidence, validity and scope of these patent rights.

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[LS]: LS Industrial Systems Co., Ltd.
LS Tower 1026-6
Hogye-dong, Dongan-gu,
Anyang-si, Gyeonggi-do 431-848
Republic of Korea

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ISO (www.iso.org/patents) and IEC (http://www.iec.ch/tctools/patent_decl.htm) maintain on-line data bases of patents relevant to their standards. Users are encouraged to consult the data bases for the most up to date information concerning patents.

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 standard 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 standard ISO/IEC 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 standard, 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 an implementation's capabilities, and thus its applicability to various time-deterministic communications needs.

1.5 Conformance

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

2 Normative references

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

IEC 61158-3-21:2010 ¹, *Industrial Communication Networks – Fieldbus specifications – Part 3-21: Data-link layer service definition – 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 8802-3:2000, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

ISO/IEC 10731:1994, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*

3 Terms, definitions, symbols and abbreviations

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

3.1 Reference model terms and definitions

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

¹ To be published.

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	[ISO/IEC 7498-1]
DL-entity	
Ph-entity	
3.1.37 (N)-interface-data-unit	[ISO/IEC 7498-1]
DL-service-data-unit (N=2)	
Ph-interface-data-unit (N=1)	

3.1.38 (N)-layer	[ISO/IEC 7498-1]
DL-layer (N=2)	
Ph-layer (N=1)	
3.1.39 (N)-service	[ISO/IEC 7498-1]
DL-service (N=2)	
Ph-service (N=1)	
3.1.40 (N)-service-access-point	[ISO/IEC 7498-1]
DL-service-access-point (N=2)	
Ph-service-access-point (N=1)	
3.1.41 (N)-service-access-point-address	[ISO/IEC 7498-1]
DL-service-access-point-address (N=2)	
Ph-service-access-point-address (N=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 standard 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

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

3.3.1

DL-segment, link, local link

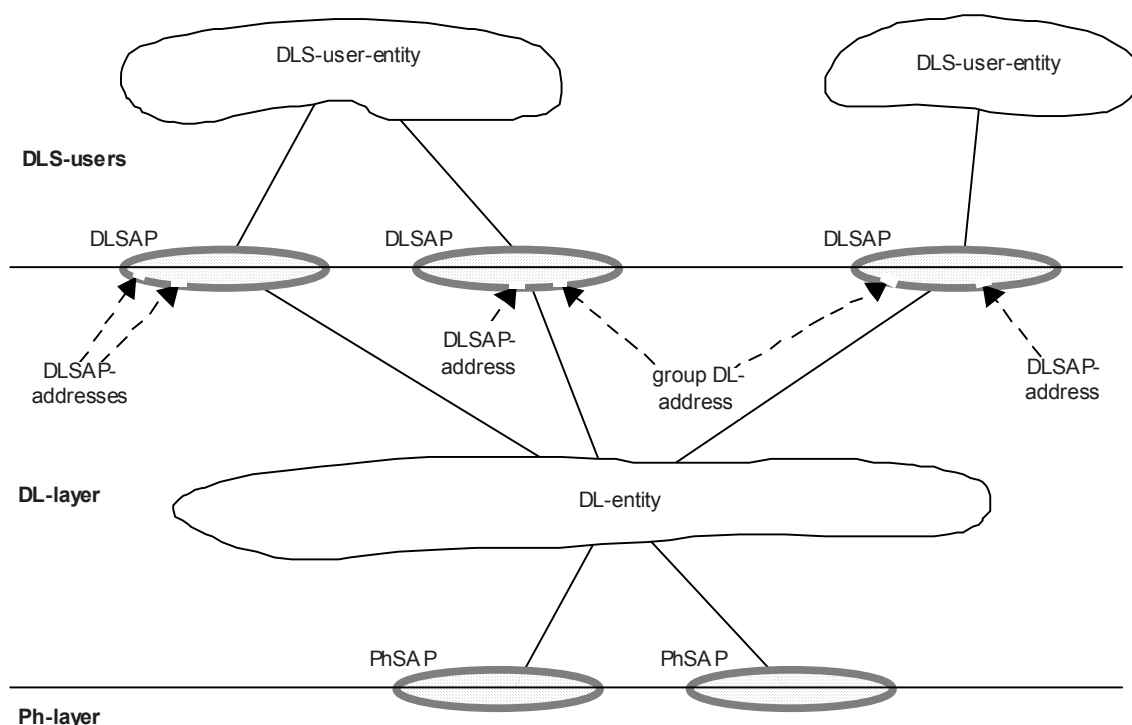
single data link (DL) subnetwork in which any of the connected data link entities (DLEs) may communicate directly, without any intervening data link relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the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

3.3.2

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 This definition, derived from ISO/IEC 7498-1, is repeated here to facilitate understanding of the critical distinction between DLSAPs and their DL-addresses.(See Figure 1.)



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.

NOTE 3 A single DLE may have multiple DLSAP-addresses and group DL-addresses associated with a single DLSAP.

Figure 1 – Relationships of DLSAPs, DLSAP-addresses, and group DL-addresses

3.3.3

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 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.

3.3.4

(individual) DLSAP-address

DL-address that designates only one DLSAP within the extended link

NOTE A single DL-entity may have multiple DLSAP-addresses associated with a single DLSAP.

3.3.5

Data-link connection endpoint address (DLCEP-address)

DL-address that designates either:

- one peer DL-connection-end-point;
- 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.

3.3.6

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

3.3.7

frame

synonym for DLPDU

3.3.8

network management

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

3.3.9

protocol

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

3.3.10

receiving DLS-user

DL-service user that acts as a recipient of DLS-user data

NOTE A DL-service user can be both a sending and receiving DLS-user concurrently.

3.3.11

sending DLS-user

DL-service user that acts as a source of DLS-user data

3.3.12

device

single DLE as it appears on one local link

3.3.13

DL- entity identifier

address that designates the (single) DLE associated with a single device on a specific local link

3.3.14

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 8802-3:2000 MAC address and 2 octet DL-address

3.3.15

ring

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

NOTE A ring may also be referred to as a loop.

3.3.16

linear topology

topology where the devices are connected in series, with two devices each connected to only one other device, and all others each connected to two other devices, for example, connected in a line

3.3.17

R-port

port in a communication device that is part of a ring structure

3.3.18

real-time

ability of a system to provide a required result in a bounded time

3.3.19

real-time communication

transfer of data in real-time

3.3.20

Real-time Ethernet (RTE)

ISO/IEC 8802-3:2000 based network that includes real-time communication

NOTE 1 Other communications can be supported, providing that the real-time communication is not compromised.

NOTE 2 This definition is based on, but not limited to, ISO/IEC 8802-3:2000. It could be applicable to other IEEE802 specifications, e.g., IEEE802.11.

3.3.21

RTE end device

device with at least one active RTE port

3.3.22

RTE port

media access control (MAC) sublayer point where an RTE is attached to a local area network (LAN)

NOTE This definition is derived from that of bridge port in ISO/IEC 10038: 1993, as applied to local MAC bridges.

3.3.23

switched network

network also containing switches

NOTE Switched network means that the network is based on IEEE802.1D and IEEE802.1Q with MAC bridges and priority operations.

3.3.24

link

transmission path between two adjacent nodes [derived from ISO/IEC 11801]

3.4 Symbols and abbreviations

3.4.1 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)

3.4.2 Type 21: Additional 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 8802-3:2000 standard with mechanisms to transfer data with predictable timing demands typical of high-performance automation. It does not change the basic principles of the Ethernet standard ISO/IEC 8802-3:2000 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 standard 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 8802-3:2000, 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 2.

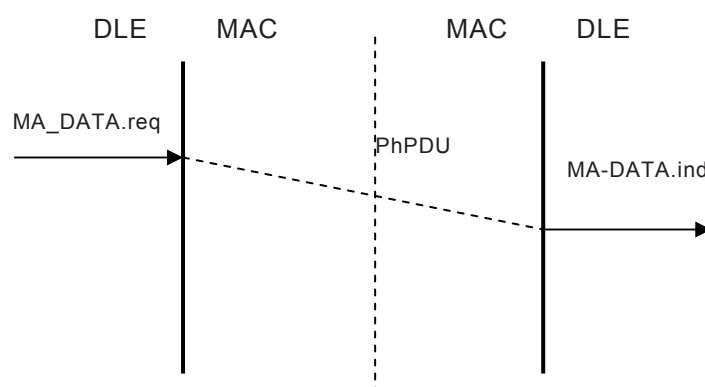


Figure 2 – Interaction of PhS primitives with DLE

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 3. The arrowheads illustrate the primary direction of the flow of data and control.

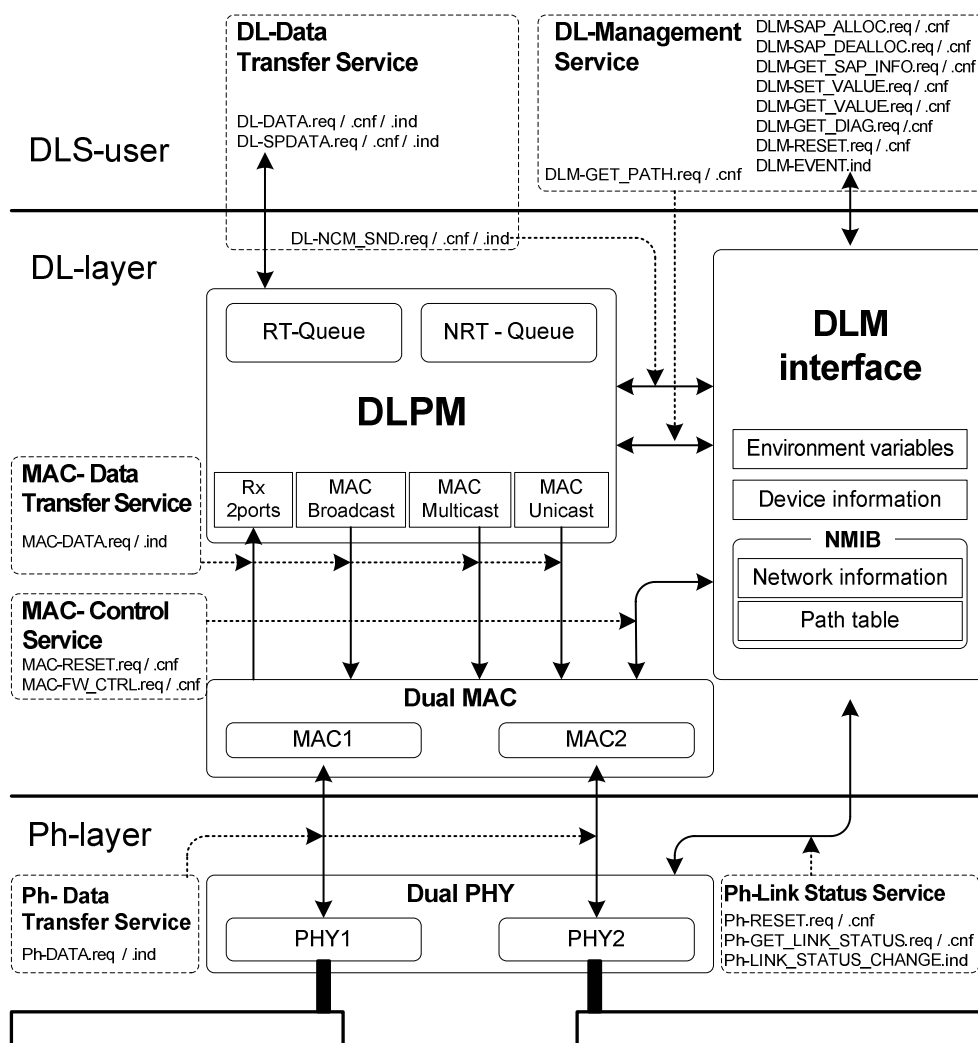


Figure 3 – Data-link layer architecture

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

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 $0, \dots, 2^{n-1}$. The data are represented as bit sequences of length n . The bit sequence

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

is assigned value defined by

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

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

Table 2 – UNSIGNEDn 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 INTEGERn 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 value defined by

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

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

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

Table 3 – INTEGERn 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_STRINGn is defined below. The n represents the octet length of the octet string.

ARRAY[n] of UNSIGNED8 OCTET_STRINGn

4.5.6 Visible String

The data type VISIBLE_STRINGn 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_STRINGn

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 standard uses DLS-user request parameters P(...) and local variables V(...) as a means of clarifying the effects of certain actions and the conditions under which those actions are valid. The standard also uses local timers T(...) 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. The standard uses local counters C(...) for performing rate measurement functions. It also uses local queues Q(...) 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 may 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(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 standard 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 standard 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 standard. 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

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 may 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	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Read/Write	Read	0x00: normal 0x01: collision 0x02: changed 0x03: collision and changed 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 8802-3:2000 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 – 15	Read/Write	Read	0 to 255: DL– entity identifier 256 to 65 535: Reserved
	Bit 16 – 63	Read/Write	Read	ISO/IEC 8802-3:2000 MAC Address

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 – 15	Read/Write	Read	0 to 255: DL– entity identifier 256 to 65 535: Reserved
	Bit 16 – 63	Read/Write	Read	ISO/IEC 8802-3:2000 MAC Address

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 – 15	Read/Write	Read	0 to 255: DL– entity identifier 256 to 65 535: Reserved
	Bit 16 – 63	Read/Write	Read	ISO/IEC 8802-3:2000 MAC Address

4.6.5.8 V(MAC_ADDR): MAC address

This variable holds 6-octet ISO/IEC 8802-3:2000 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 8802-3:2000 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	Waiting for NCM_ADV_THIS message from R-port1
	Bit 3	Read/Write	Read	Waiting for NCM_MEDIA_LINKED message from R-port1
	Bit 4	Read/Write	Read	R-port1 state confirm
	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	Waiting for NCM_ADV_THIS message from R-port2
	Bit 11	Read/Write	Read	Waiting for NCM_MEDIA_LINKED message from R-port2
	Bit 12	Read/Write	Read	R-port2 state confirm
	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 – 4	Read	Read	0x00: minor version 0 0x01: minor version 1 0x02: minor version 2 0x03: minor version 3 0x04: minor version 4 0x05: minor version 5 0x06: minor version 6 0x07: minor version 7
	Bit 5 – 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.

Table 20 – Variables to support managing network information

Parameter	Data type	Default value	Description
Topology	UNSIGNED8	NET_TPG_SA	Network topology
Collision count	UNSIGNED8	0	DL–entity identifier collision counter between remote devices
Device count	UNSIGNED16	1	Device counter for the network segment
Topology change count	UNSIGNED16	0	Network topology change counter
Network flags	UNSIGNED16	0	Network event flags
Last topology change time	TIMEOFDAY	0	Date and time when the network topology last was changed.
Reserved	UNSIGNED16	0	Reserved
RNMP device UID	UNSIGNED64	INVALID_UID	UID of the RNMP device
RNMS device UID	UNSIGNED64	INVALID_UID	UID of the RNMS device
LNM device UID for R-port1	UNSIGNED64	INVALID_UID	UID of the LNM device in R-port1 direction
LNM device UID for R-port2	UNSIGNED64	INVALID_UID	UID of the LNM device in R-port2 direction

4.6.6.2 V(TPG): Topology

This variable holds the type of network topology. The value of this variable is defined as shown in Table 21.

Table 21 – Topology

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED8	Read/Write	Read	Network topology 0x01: standalone 0x02: line topology 0x03: ring topology

4.6.6.3 C(COLL_CNT): Collision count

This variable holds the DL– entity identifier collision count for remote devices. The value is incremented by the DLM when a remote DL– entity identifier collision is detected and the value is decremented when the collision is cleared. This variable is defined in Table 22.

Table 22 – Collision count

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED8	Read/Write	Read	0 to 255: remote DL– entity identifier collision count

4.6.6.4 C(DEV_CNT): Device Count

This variable holds the total number of devices on the network, to a maximum of 256. It is defined as shown in Table 23.