

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

**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**

WITNESS



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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

XD

ICS 25.040.40; 35.100.20; 35.110

ISBN 978-2-88912-860-0

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

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

FOREWORD

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International Standard IEC 61158-4-21:2010 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This standard cancels and replaces IEC/PAS 62573 published in 2008. This first edition constitutes a technical revision.

This bilingual version published in 2012-01 corresponds to the English version published in 2010-08.

The text of this standard is based on the following documents:

FDIS	Report on voting
65C/605/FDIS	65C/619/RVD

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

The French version has not been voted upon.

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

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

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

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- withdrawn;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

NOTE The revision of this standard will be synchronized with the other parts of the IEC 61158 series.

Withdrawn

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 Tower 1026-6
 Hogle-dong, Dongan-gu,
 Anyang-si, Gyeonggi-do 431-848
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Withdrawn

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 61158-3-21:2010¹, *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

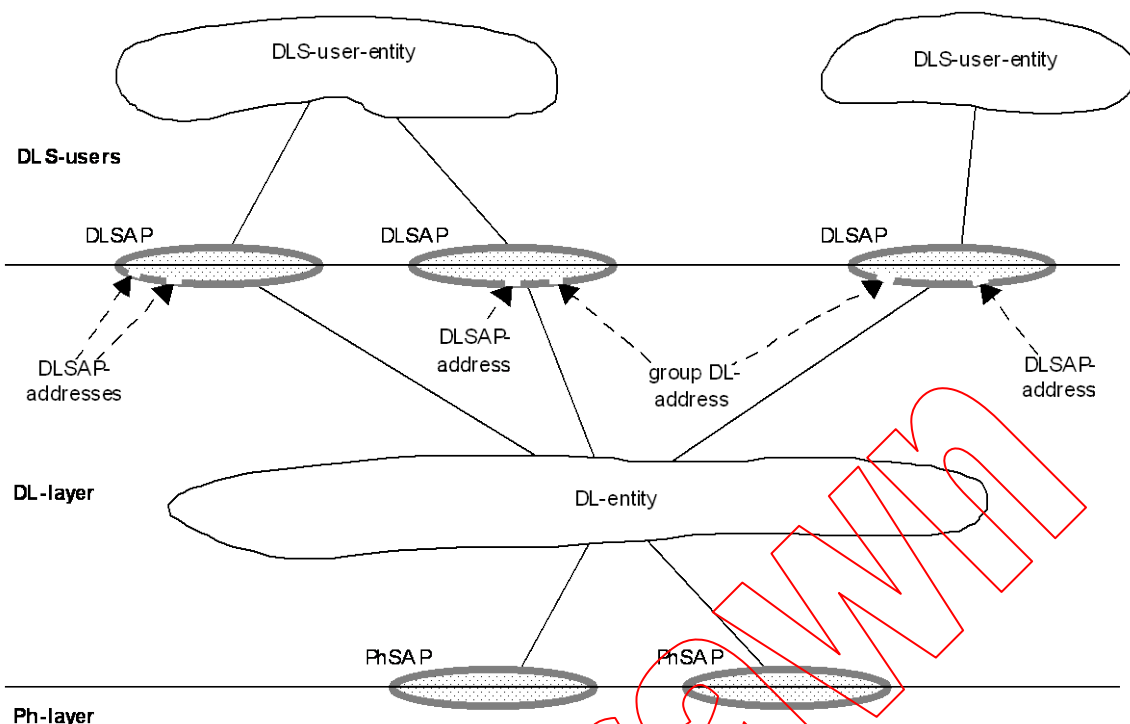
single data link (DL) subnetwork in which any of the connected data link entities (DLEs) may communicate directly, without any intervening data link relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the 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
LNM	line network manager
PO	power on
PnP	plug and play
RNM	ring network manager
RNMP	primary ring network manager
RNMS	secondary ring network manager
RNAC	ring network auto configuration
UID	device unique identification
Type 21 NMIB	Type 21 network management information base

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.

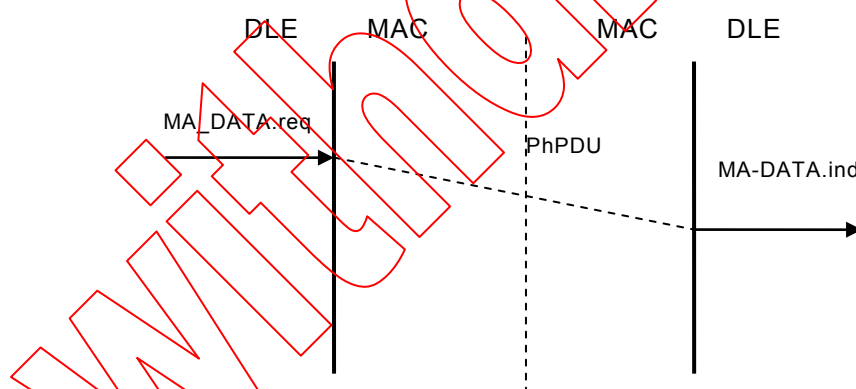


Figure 2 – Interaction of PhS primitives with DLE

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.

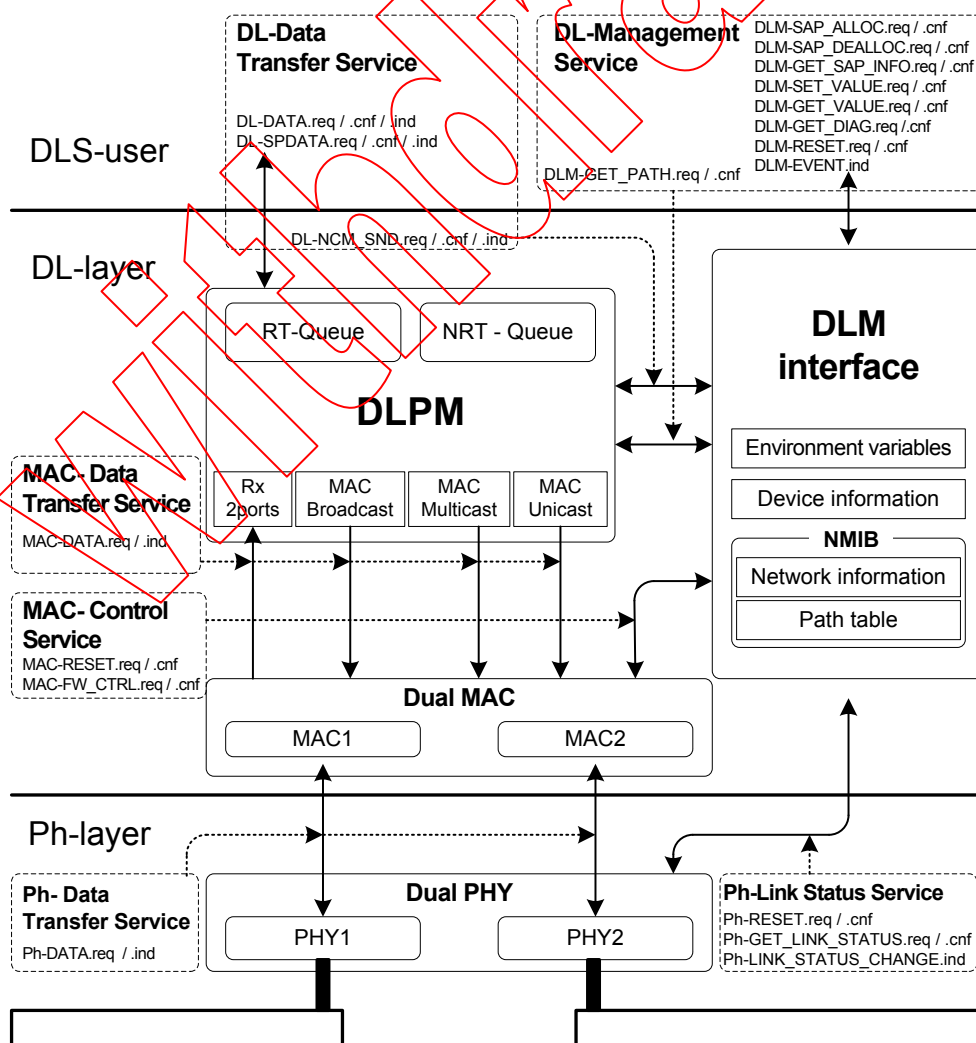


Figure 3 – Data-link layer architecture

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.

Table 23 – Device count

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Read/Write	Read	0: not used 1 to 256: device count 257 to 65 535: reserved

4.6.6.5 C(TPG_CHG_CNT): Topology change count

This variable holds the topology change count. The value is incremented by the DLM when the network is changed from ring to line or from line to ring topology. It is defined as shown in Table 24.

Table 24 – Topology change count

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Read/Write	Read	0 to 65 535: Topology change count

4.6.6.6 V(TPG_CHG_TIME): Last topology change time

This variable holds the date and time when the network topology was last changed. It is defined as shown in Table 25.

Table 25 – Last topology change time

Data type	Access type DLM	Access type DLS-user	Value/Description
TIMEOFDAY	Read/Write	Read	The date and time when the network topology was last changed

4.6.6.7 V(UID_RNMP): RNMP device UID

This variable holds the device UID selected as the RNMP on the network. It is defined as shown in Table 26.

Table 26 – RNMP device UID

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

4.6.6.8 V(UID_RNMS): RNMS device UID

This variable holds the UID of the device selected as the RNMS on the network. It is defined as shown in Table 27.

Table 27 – RNMS device UID

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

4.6.6.9 V(UID_LNM_RP1): LNM device UID for R-port1

In a Type 21 line network, the two end devices are automatically selected as the LNMs. This variable holds the UID of the device selected as the LNM in the R-port1 direction. It is defined as shown in Table 28.

Table 28 – LNM device UID for 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

4.6.6.10 V(UID_LNM_RP2): LNM device UID for R-port2

In a Type 21 line network, two end devices are automatically selected as the LNMs. This variable holds the UID of the device selected as the LNM in the R-port2 direction. It is defined as shown in Table 29.

Table 29 – LNM device UID for 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

4.6.6.11 V(NET_FLAG): Network flags

This variable holds the event flags to notify the DLMS-user of network events. When any bit in this variable is set, the DLM generates a DLM-event indication service primitive to notify the DLMS-user of the event. After the DLM-event service has completed successfully, the designated bit in this variable is cleared. Network flags are defined in Table 30.

Table 30 – Network flags

Data type	Position	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Bit 0	Read/Write	Read	Network Topology Change Status 0x00: Normal 0x01: Network topology has changed
	Bit 1	Read/Write	Read	Network DL– entity identifier Collision Status 0x00: Normal 0x01: Network DL– entity identifier collision detected
	Bit 2	Read/Write	Read	In Device Status 0x00: Normal 0x01: New device has joined the network
	Bit 3	Read/Write	Read	Out Device Status 0x00: Normal 0x01: Device has left the network
	Bit 4 – 63	—	—	Reserved

The bit fields in the network flags are defined as follows:

a) Network Topology Change Status;

This bit is set to TRUE by the DLM when it detects that the network topology has changed. This bit is reset to FALSE when the DLMS-user has been notified using the EVENT_NET_TPG_CHG service.

b) Network DL– entity identifier Collision Status;

This bit is set to TRUE by the DLM when it detects a DL– entity identifier collision on the network. This bit is reset to FALSE when the DL– entity identifier collision is cleared.

c) In Device Status;

This bit is set to TRUE by the DLM when it detects that a new device has joined the network. This bit is reset to FALSE when the DLMS-user has been notified using the EVENT_IN_DEVICE service.

d) Out Device Status.

This bit is set to TRUE by the DLM when it detects that a device has left the network. This bit is reset to FALSE when the DLMS-user has been notified using the EVENT_OUT_DEVICE service.

4.6.7 Variables and counter to support a device path information management

4.6.7.1 General

The path table is managed by the DLM, and it is made up of table items related to the other Type 21 devices on the network. The variables and counters for a table item are defined in Table 31.

Table 31 – Variables and counter to support managing path information

Parameter	Data type	Default value	Description
DL– entity identifier	UNSIGNED16	INVALID_ADDR	DL– entity identifier
Hop count for R-port1	UNSIGNED16	INVALID_HOP_CNT	Hop count in R-port1 direction
Hop count for R-port2	UNSIGNED16	INVALID_HOP_CNT	Hop count in R-port2 direction
Preferred R-port	UNSIGNED8	INVALID_R_PORT	R-port with the smaller hop count value to the peer device.
Destination R-port	UNSIGNED8	INVALID_R_PORT	Selected R-port for sending a frame to the destination DL– entity identifier.
Device state	UNSIGNED8	0	Peer device's DLM State
MAC address	UNSIGNED48	0	Peer device's ISO/IEC 8802-3:2000 MAC address
Port information	UNSIGNED16	0	Peer device's local R-port information
Protocol version	UNSIGNED8	0	Peer device's protocol version
Device type	UNSIGNED16	0	Peer device's application device type
Device description	VISIBLE_STRING[16]	" "	Peer device's description
Device UID	UNSIGNED64	INVALID_UID	Peer device's Device UID
Device UID for R-port1	UNSIGNED64	INVALID_UID	Device UID of the device connected through the peer device's R-port1
Device UID for R-port2	UNSIGNED64	INVALID_UID	Device UID of the device connected through the peer device's R-port2
In net count	UNSIGNED16	0	The number of times that the peer device has joined in the network.
In net time	TIMEOFDAY	0	The date and time when the peer device last joined the network.
Out net count	UNSIGNED16	0	The number of times that the peer device has been disconnected from the network.
Out net time	TIMEOFDAY	0	The date and time when the peer device was last disconnected from the network

4.6.7.2 V(path-DL_ADDR): DL– entity identifier

See 4.6.5.2.

4.6.7.3 C(path-HOP_CNT_RP1): Hop count for R-port1

This variable indicates the frame forwarding counts for sending a frame from the local device to the peer device through the R-port1. It is defined as shown in Table 32.

Table 32 – Hop count for R-port1 direction

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Read/Write	Read	0 to 255: Hop count for R-port1 256 to 65 535: Reserved

4.6.7.4 C(path-HOP_CNT_RP2): Hop count for R-port2

This variable indicates the frame forwarding counts for sending a frame from the local device to the peer device through the R-port2. It is defined as shown in Table 33.

Table 33 – Hop count for R-port2 direction

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Read/Write	Read	0 to 255: hop count for R-port2 256 to 65 535: Reserved

4.6.7.5 V(path-PREFER_RP): Preferred R-port

This variable holds the preferred R-port for sending a frame from the local device to the peer device without regard for the RNMP or RNMS. This variable is determined as the R-port that has the smaller hop count value for the peer device. If the R-port1 hop count and R-port2 hop count have the same value, R-port1 is selected as the preferred R-port. This variable is defined as shown Table 34.

Table 34 – Preferred R-port

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED8	Read/Write	Read	0: Invalid 1: R-port1 2: R-port2 3 to 255: Reserved

4.6.7.6 V(path-DST_RP): Destination R-port

This variable holds the destination R-port for sending a frame from the local device to the peer device. In a line network, this variable has the same value as the Preferred R-port. However, in a ring network, this variable is determined based on the RNMP and RNMS position, because the preferred path may be blocked by the RNMP or RNMS. In this case, the destination R-port is selected as the other R-port. It is defined as shown in Table 35.

Table 35 – Destination R-port

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED8	Read/Write	Read	0: Invalid 1: R-port1 2: R-port2 3 to 255: Reserved

4.6.7.7 V(path-DEV_STATE): Device State

See 4.6.5.4.

4.6.7.8 V(path-MAC_ADDR): MAC address

See 4.6.5.8.

4.6.7.9 V(path-PORT_INFO): Port information

See 4.6.5.9.

4.6.7.10 V(path-PROTOCOL_VER): Protocol Version

See 4.6.5.10.

4.6.7.11 V(path-DEV_TYPE): Device type

See 4.6.5.11.

4.6.7.12 V(path-DEV_DESC): Device Description

See 4.6.5.12.

4.6.7.13 V(path-DEV_UID): Device UID

See 4.6.5.5.

4.6.7.14 V(path-DEV_UID_RP1): Device UID for R-port1

See 4.6.5.6.

4.6.7.15 V(path-DEV_UID_RP2): Device UID for R-port2

See 4.6.5.7.

4.6.7.16 C(path-IN_NET_CNT): In net count

This variable holds the number of times that the peer device has joined the network. When a line network is merged into an existing network, the variables for the newly joined devices are incremented together. This variable is defined as shown in Table 36.

Table 36 – In net count

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Read/Write	Read	0 to 65 535: the number of times that the peer device has joined the network

4.6.7.17 V(path-IN_NET_TIME): In net time

This variable holds the date and time when the peer device last joined in the network. This variable is defined as shown in Table 37.

Table 37 – In net time

Data type	Access type DLM	Access type DLS-user	Value/Description
TIMEOFDAY	Read/Write	Read	The date and time when the device last joined in the network

4.6.7.18 C(path-OUT_NET_CNT): Out net count

This variable holds the number of times that the peer device has been disconnected from the network. When a device or a group of devices are disconnected from the network, the variables for the disconnected devices are incremented together. This variable is defined as shown in Table 38.

Table 38 – Out net count

Data type	Access type DLM	Access type DLS-user	Value/Description
UNSIGNED16	Read/Write	Read	0 to 65 535: the number of times that the device has been disconnected from the network

4.6.7.19 V(path-OUT_NET_TIME): Out net time

This variable holds the date and time when the device was last disconnected from the network. This variable is defined as shown in Table 39.

Table 39 – Out net time

Data type	Access type DLM	Access type DLS-user	Value/Description
TIMEOFDAY	Read/Write	Read	The date and time when the device was last disconnected from the network

4.6.8 Variables, counters, timers, and queues to support path table management

4.6.8.1 Path table

The path table is composed of items related to the other devices on the network. It is managed by the DLM in the form of an array table filled with the path information of each device (see 4.6.7). The maximum size of the path table is a function of MAX_ADDR (see 4.6.2.2) as follows:

Path table: Array[n] of device's path information, $n = \text{MAX\_ADDR} + 1$

5 General structure and encoding

5.1 Overview

The DLL and its procedures are necessary to provide services to the DLS-user using the services available from the physical layer. This clause describes the structure and semantics of the management application protocol data unit (MAPDU), the DLPDU, and the procedure commonly used in this standard. This portion is identical to and fully compliant with the ISO/IEC 8802-3:2000 standard.

NOTE In this clause, any reference to bit k of an octet is a reference to the bit whose weight in a one-octet unsigned integer is 2^k . This is sometimes referred to as "little-endian" bit numbering.

5.2 MAPDU structure and encoding

The local MAC sublayer uses the service primitives provided by the physical layer service (PLS) sublayer specified by ISO/IEC 8802-3:2000 Clause 2. These service primitives provided by the PLS sublayer are mandatory:

- a) MA-DATA request;

b) MA-DATA indication.

5.3 Common MAC frame structure, encoding and elements of procedure

5.3.1 MAC frame structure

5.3.1.1 MAC frame format for the Type 21 DLPDU

The DLPDU for the Type 21 is encapsulated in the data field of a MAC frame as specified by ISO/IEC 8802-3:2000, Clause 3. The value of the Length/Type field is 88FE_H, which is authorized and registered as the protocol identification number by the IEEE Registration Authority, to identify a Type 21 fieldbus frame. Figure 4 shows the Type 21 DLPDU structure.

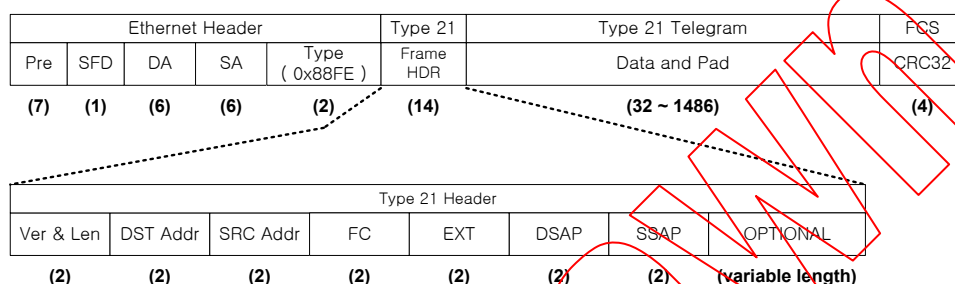


Figure 4 – Common MAC frame format for Type 21 DLPDU

5.3.1.2 MAC frame format for Type 21 fieldbus sporadic DLPDU

The MAC frame format used for Type 21 fieldbus sporadic data transmission is identical to the frame format of Ethernet V2.0 specified by ISO/IEC 8802-3:2000, Clause 3 “Media access control frame structure,” and the value of the Length/Type field is anything other than 0x88FE. Figure 5 shows the frame format for a Type 21 fieldbus sporadic DLPDU.

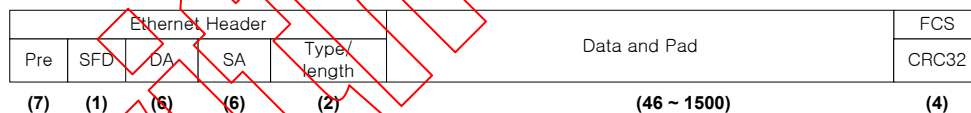


Figure 5 – MAC frame format for other protocols

5.3.2 Elements of the MAC frame

5.3.2.1 General

The elements of the MAC frame are the preamble, the start frame delimiter, the destination MAC address, the source MAC address, the length/type code, and the frame check sequence (FCS), all as specified by ISO/IEC 8802-3:2000, Clause 3.

5.3.2.2 Preamble field

The preamble of MAC frame is identical to ISO/IEC 8802-3:2000, Clause 3. This is a 7-octet field that is used to allow the physical signalling portion of the circuitry to reach its steady-state synchronization with the receiving frame timing. The preamble pattern is:

“10101010 10101010 10101010 10101010 10101010 10101010 10101010”

The bits are transmitted in order from left to right. The nature of the pattern is such that for Manchester encoding, it appears as a periodic waveform on the medium that enables bit synchronization. It should be noted that the preamble ends with a “0”.

5.3.2.3 Start Frame Delimiter

The Start Frame Delimiter (SFD) is identical to ISO/IEC 8802-3:2000, Clause 3. The SFD field is the bit pattern sequence “10101011.” It immediately follows the preamble pattern and indicates the start of a frame.

5.3.2.4 Destination MAC Address field

The Destination MAC Address field is identical to ISO/IEC 8802-3:2000, Clause 3. It specifies the device(s) for which the frame is intended, and may be an individual or multicast (including broadcast) address. The destination MAC address is set to the corresponding DL– entity identifier by the DLM. Type 21 also defines a special MAC address, 00-E0-91-02-05-99 (NCM_MAC_ADDR) for sharing network management information using the DLM services. Every message received through the NCM_MAC_ADDR is delivered to the DLM to update the network management information. The message is not forwarded by the MAC layer but the message is examined and forwarded by the DLM.

5.3.2.5 Source MAC address field

The Source MAC Address field is identical to ISO/IEC 8802-3:2000, Clause 3. This field specifies the device sending the frame and is not interpreted by the DLE or the CSMA/CD MAC sublayer.

5.3.2.6 Length/type field

The Length/type field is identical to ISO/IEC 8802-3:2000, Clause 3 “Media access control frame structure.” To be identified as a Type 21 frame, the value of the Length/type field is set to 0x88FE, which is authorized and registered as the protocol identification number for RTE-Type 21 by the IEEE Registration Authority. Every frame with a value other than 0x88FE is identical to the frame in ISO/IEC 8802-3:2000, Clause 3, and is processed as a Type 21 fieldbus sporadic data frame.

5.3.2.7 Frame check sequence

The FCS field is identical to ISO/IEC 8802-3:2000, Clause 3.

5.3.3 Elements of the Type 21 DLPDU

5.3.3.1 Version and Length

This field stores the protocol version and the length of a Type 21 telegram or data field. This Version and Length field is specified in Figure 6. The version is represented by 2 bits for the major version and 3 bits for the minor version, and the length is given by 11 bits.

Version and Length															
Version					Length										
15	14	13	21	11	10	9	8	7	6	5	4	3	2	1	0

Figure 6 – Version and Length field

The parts of this field and permissible values are described in Table 40.

Table 40 – Version and Length

Field Name		Position	Value/Description
Length		Bit 0 – 10	Frame length including FCS field
Version	Minor	Bit 11 – 13	Type 21 Protocol minor version 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
	Major	Bit 14 – 15	Type 21 Protocol major version 0x00: major version 1 0x01: major version 2 0x02: major version 3 0x03: major version 4

5.3.3.2 DST_addr**5.3.3.2.1 General**

This field indicates the destination DL– entity identifier of the node to which the frame is sent. This value is represented as shown in Figure 7.

Destination DL–address															
DST_Addr															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure 7 – DST_addr field

The separate field and its permissible values are described in Table 41.

Table 41 – Destination DL– entity identifier

Field Name	Position	Value/Description
DST_addr	Bit 0 – 15	0xFFFF: broadcast address 0xFFFE: network control address (C_NCM_ADDR) 0xFFFD–0xFFDE: user-defined multicast address 0xFFDD: invalid address 0x0100 to 0xFFDC: reserved 0x0000 to 0x00FF: regular Type 21 DL– entity identifier

5.3.3.2.2 Broadcast address

If the destination DL– entity identifier is 0xFFFF, the destination MAC address field contains the ISO/IEC 8802-3:2000 MAC address.

5.3.3.2.3 Network control address

If the destination DL– entity identifier is 0xFFFE (C_NCM_ADDR), the destination MAC address field contains C_NCM_MAC_ADDR. However, NCM_LINK_ACTV and NCM_ADV_THIS messages are transmitted using C_NCM_ADDR as the destination DL– entity identifier.

NOTE C_NCM_ADDR cannot be accessed by the DLS-user.

5.3.3.2.4 User-defined multicast address

A user-defined multicast address is used to indicate multiple recipients. However, user-defined multicast addressing is not a mandatory feature in this standard. It is designed for use in a special application system that requires multicast communication. Therefore, user-defined multicast addressing is not interoperable between heterogeneous devices. The destination DL– entity identifier range from 0xFFFFD–0xFFDE is used to specify the user-defined multicast address. However, the method of using the user-defined multicast address is not specified in this standard, and is considered a local responsibility. This standard does not restrict the use of user-defined multicast addresses, nor is it a mandatory feature.

5.3.3.3 SRC_addr

This field indicates the source DL– entity identifier of the node from which the frame is generated. This value is represented as shown in Figure 8.

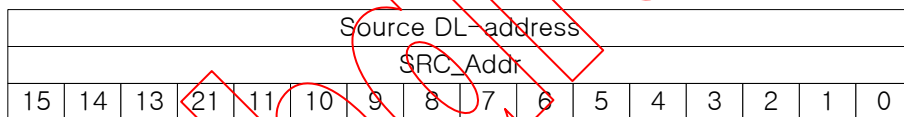


Figure 8 – SRC_addr field

The separate field and its permissible values are described in Table 42.

Table 42 – Source DL– entity identifier

Field Name	Position	Value/Description
SRC_addr	Bit 0 – 15	Source DL– entity identifier

5.3.3.4 Frame Control (FC)

5.3.3.4.1 General

The Frame Control field indicates the frame control information. This value is represented as shown in Figure 9.

Frame Control															
VoE	RES	PRI		ToS				NCMT							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

key

VoE: Validation of Extension code

RES: Reserved

PRI : Priority

ToS: Type of Service

NCMT: Network control message type

Figure 9 – Frame Control Field

The separate field and its permissible values are described in Table 43.

Table 43 – Frame control

Field Name	Position	Value/Description
Network Control Message Type (NCMT)	Bit 0 – 7	0x00: reserved 0x01: NCM_FAMILY_REQ 0x02: NCM_FAMILY_RES 0x03: NCM_MEDIA_LINKED 0x04: NCM_ADV_THIS 0x05: NCM_LINE_START 0x06: NCM_RING_START 0x07: NCM_ACK_RNMS 0x08: NCM_RETRY_RNMS 0x09 to 0xFF: reserved
Type of Service (ToS)	Bit 8 – 11	0x00: Network Control Message (NCM) 0x01: unconfirmed service request 0x02–0x0F: Reserved
Priority (PRI)	Bit 12 – 13	0x00: lowest priority ... 0x03: highest priority
Reserved	Bit 14	Reserved
Validation of Extension code (VoE)	Bit 15	0x00: EXT Code is invalid 0x01: EXT Code is valid

5.3.3.4.2 Validation of extension code (VoE)

If the frame has the extension field, VoE is set to TRUE; otherwise VoE is set to FALSE.

5.3.3.4.3 Priority

This field indicates the frame priority. This field contains the value of the message priority parameter for the DL service. The highest priority is 0x03 and the lowest is 0x00.

5.3.3.4.4 Type of service (ToS)

This field indicates the type of DL service. A value of 0x00 indicates a network control message among DLMs, and 0x01 indicates the unconfirmed service request among DLS-users.

5.3.3.4.5 Network Control Message Type (NCMT)

5.3.3.4.5.1 General

NCMT field indicates the type of network control message.

5.3.3.4.5.2 NCM_FAMILY_REQ

NCMT: 0x01

This network control message is used to ask the device newly connected through an R-port if it is a Type 21 device. This network control message is transmitted through the newly activated R-port. This message shall not be forwarded to the other port.

5.3.3.4.5.3 NCM_FAMILY_RES

NCMT: 0x02

This network control message is used to confirm whether the recipient is a Type 21 device when the recipient receives the NCM_FAMILY_REQ message from the newly linked device. This message is transmitted through the R-port used to receive the NCM_FAMILY_REQ message. This message shall not be forwarded to the other port.

5.3.3.4.5.4 NCM_MEDIA_LINKED

NCMT: 0x03

This network control message is used to indicate that a new Type 21 link has been established through the R-port. This message is transmitted through the newly activated R-port. The destination DL- entity identifier contains C_NCM_ADDR. When the DLM receives this message, the DLM increments the hop count in the frame, and forwards the frame through the other R-port. This message is discarded by the LNM or the device that generated the message.

5.3.3.4.5.5 NCM_ADV_THIS

NCMT: 0x04

This network control message is used to transmit the recipient's local device information when the recipient receives NCM_MEDIA_LINKED message from a new device on the network. This message is transmitted through the R-port that is used to receive the NCM_MEDIA_LINKED message. The destination DL- entity identifier contains C_NCM_ADDR. When the DLM receives this message, the DLM increments the hop count in the frame, and forwards the frame through the other R-port. This message is discarded by the LNM or the device that generated the message.

5.3.3.4.5.6 NCM_LINE_START

NCMT: 0x05

This network control message is used to broadcast that the network topology has been automatically configured as a line network. This message is initiated by the DLM whose state is changed to LNM when the existing line network is divided into two line networks, or when a link failure is detected in a ring network and the network is reconfigured as a line network. This message is broadcast on the network using the broadcast address.

5.3.3.4.5.7 NCM_RING_START

NCMT: 0x06

This network control message is used to broadcast that the network topology has been automatically configured as a ring network. This message is initiated and broadcast through both R-ports by the DLM whose state is changed to RNMP.

5.3.3.4.5.8 NCM_ACK_RNMS

NCMT: 0x07

This network control message is used by the RNMS device to broadcast that the RNMS has been successfully selected. This message is transmitted from the RNMS to the RNMP.

5.3.3.4.5.9 NCM_RETRY_RNMS

NCMT: 0x08

This network control message is used to request a retransmission of the NCM_ACK_RNMS message from the RNMS device in the case where the RNMP device did not initially receive it. The NCM_RETRY_RNMS message is transmitted from the RNMP to the RNMS.

5.3.3.5 Extension (EXT)

5.3.3.5.1 General

This field exists when the VoE bit in the frame control field is set to TRUE. The extension field is specified as shown in Figure 10.

Extension Code															
G	Extension Type								Extension Length						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

key
G: Group Mask

Figure 10 – Extension field

The separate field and its permissible values are described in Table 44.

Table 44 – Extension

Field Name	Position	Value/Description
Extension Length	Bit 0 – 7	0 to 255: the length of extension field
Extension Type	Bit 8 – 14	0: Invalid extension type 1 to 127: reserved for future use
Group Mask Enable	Bit 15	0x0: Group mask is enabled 0x1: Group mask is disabled

5.3.3.5.2 Group mask enable

Group Mask Enable is a bit field to specify whether the frame is to be accepted by the peer device or not, when the frame is broadcast or multicast. When the value is set to TRUE, group mask is enabled in the peer device that receives the frame. Otherwise, group mask is disabled in the peer device. When the group mask is enabled, the group mask fields are appended in the option field (see 5.3.3.8).

5.3.3.5.3 Extension type

This field indicates the type of extension field. The value 0x00 indicates an invalid extension type and the other values are reserved for future use.

5.3.3.5.4 Extension length

This field indicates the length of the extension field. When group mask enable is set to TRUE and extension type is set to 0x00, the extension length specifies the length of the group mask field. When group mask enable is set to FALSE and extension type is set to a value other than 0x00, extension length specifies the length of the extension field. When group mask enable is set to TRUE and extension type is not set to 0x00, the first two octets specify the length of the group mask field and the next two octets specify the extension type.

5.3.3.6 DSAP

This field indicates the SAP of the DLE to which the DLPDU is sent. The permissible values are in the range 0 to 65 535. The DSAP is specified as shown in Figure 11 and Table 45.

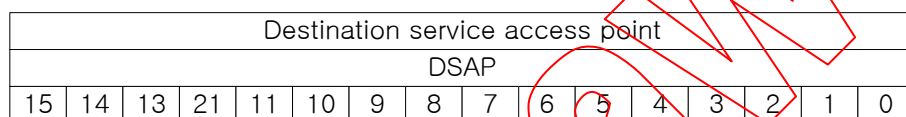


Figure 11 – DSAP field

Table 45 – Destination service access point

Field Name	Position	Value/Description
DSAP	Bit 0 – 15	Service access point of destination DLE

5.3.3.7 SSAP

This field indicates the SAP of the DLE from which the DLPDU is generated. The permissible values are in the range 0 to 65 535. The SSAP is specified as shown in Figure 12 and Table 46.

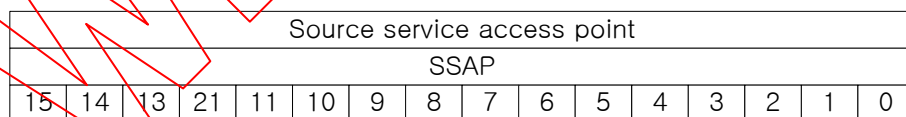


Figure 12 – Source service access point field

Table 46 – source service access point

Field Name	Position	Value/Description
SSAP	Bit 0 – 15	Service access point of source DLE

5.3.3.8 Option

5.3.3.8.1 General

This field indicates the option field when the VoE (see 5.3.3.4.2) is set to TRUE. The option field is used to indicate group mask information or other additional information. The maximum length of option field is limited to 256 octets.

5.3.3.8.2 Length of group mask and extension information

This field indicates the length of group mask and extension information. When group mask enable is set to TRUE and the extension type is not 0x00, the first two octets indicate the length of the group mask field and the next two octets indicate the length of the extension type field. When group mask enable is set to FALSE and the extension type is 0x00, the length of group mask and extension information field is ignored.

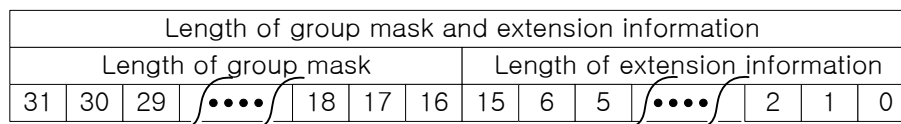


Figure 13 – Length of group mask and extension information

5.3.3.8.3 Group mask

This field uses a bit sequence to indicate the receipt selection of a message. When group mask enable is set to TRUE, the group mask field is appended in 4-octet units, for example, 4, 8, 12 ... 32 octets. Each bit indicates the receipt selection of the frame for the corresponding DL– entity identifier. A 1 means TRUE for frame receipt and 0 means FALSE. The first bit indicates the frame receipt option for highest DL– entity identifier. Figure 14 shows the bit sequence order of group mask field when its length is set to 255. When the extension type is set to 0x00, the group mask field is appended to the option field. Otherwise, the group mask field is appended after the length of group mask and extension information fields.

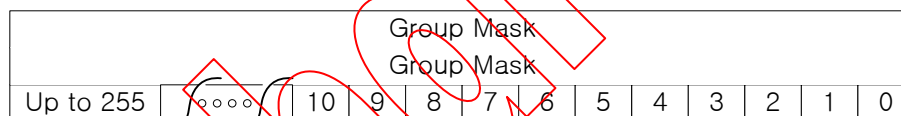


Figure 14 – Group mask option field

5.3.3.8.4 Extension information

This field is reserved for future extension. This field contains 4 octets of extension information.

5.3.3.9 Data and pad

This field indicates the data field received from a DLS-user.

5.4 Order of bit transmission

The order of bit transmission is identical to ISO/IEC 8802-3:2000, Clause 3. Each octet of the DLPDU with the exception the FCS is transmitted with the low-order bit first.

5.5 Invalid DLPDU

An invalid DLPDU shall be defined as one that meets at least one of the following conditions; this is almost identical to ISO/IEC 8802-3:2000, Clause 3:

- the frame length is inconsistent with a length value specified in the Length/type field. If the Length/type field contains a type value defined by ISO/IEC 8802-3:2000, 3.2.6, then the frame length is assumed consistent with this field and should not be considered an invalid DLPDU on this basis;
- it is not an integral number of octets in length;
- the bits of the incoming DLPDU excluding the FCS field do not generate a CRC value identical to the one received;

d) it is inconsistent with a F-type value of Type 21 fieldbus DLPDU.

The contents of invalid DLPDUs shall not be passed to the DL-user or DLE. The occurrence of an invalid DLPDU may be communicated to the network management.

NOTE Invalid DLPDUs may be ignored, discarded, or used in a private manner by a DL-user other than the RTE DL-user. The use of such DLPDUs is beyond the scope of this standard.

6 DLPDU structure and procedure

6.1 General

This clause defines the structure, contents, and encoding for each type and format of the DLPDU, along with procedural elements. Subclauses describe the structure, contents, parameters, and encoding of the DLPDU, along with the Type 21-specific part of the DLPDU structure, which is shown in Figure 4. The aspects relating to sending and receiving by DLS-users and their DLEs are also described.

NOTE In this clause, any reference to bit K of an octet is a reference to the bit whose weight in a one-octet unsigned integer is 2^K , and this is sometimes referred to as "little-endian" bit numbering.

6.2 Common DLPDU Field

6.2.1 General

Figure 15 shows the common DLPDU field. The Version and Length field is common to every DLPDU and is not described further for each DLPDU type.

Version and Length															
Version					Length										
15	14	13	21	11	10	9	8	7	6	5	4	3	2	1	0

Figure 15 – Common DLPDU field

6.2.2 Version

This field indicates the Type 21 protocol version with a 5 bit sequence. The highest 2 bits specify the major version and the lowest 3 bits specify the minor version (see 5.3.3.1).

6.2.3 Length

This field indicates the length of the data field in octets including the FCS field. The permissible values are in the range 12 to 1 498.

6.3 DL-DATA Transfer

6.3.1 DT DLPDU

6.3.1.1 General

The DT DLPDU is used to carry Type 21 data from one device to another.

6.3.1.2 DT DLPDU structure

Figure 16 shows the process of building a DT DLPDU and Figure 17 shows the structure of the DT DLPDU.