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**Industrial communication networks – Fieldbus specifications –
Part 4-28: Data-link layer protocol specification – Type 28 elements**

**Réseaux de communication industriels – Spécifications des bus de terrain –
Partie 4-28: Spécification du protocole de la couche liaison de données –
Éléments de type 28**



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IEC 61158-4-28 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation. It is an International Standard.

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

Draft	Report on voting
65C/1206/FDIS	65C/1235/RVD

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

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

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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 61158-1.

The data-link protocol provides the data-link service by making use of the services available from the physical layer. The primary aim of this document is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer data-link entities (DLEs) at the time of communication. These rules for communication are intended to provide a sound basis for development in order to serve a variety of purposes:

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

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

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-28: Data-link layer protocol specification – Type 28 elements

1 Scope

1.1 General

The data-link layer provides several types of messaging communications between devices in an automation environment.

This part of IEC 61158 provides a means of connecting devices through a partial mesh network, such that most failures of an interconnection between two devices can be circumvented. In common practice, the devices are interconnected in a non-redundant hierarchical manner reflecting application needs.

1.2 Specifications

This document specifies

- 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) the structure of the fieldbus DLPDUs used for the transfer of data and control information by the protocol of this document, and their representation as physical interface data units.

1.3 Procedures

The procedures are defined in terms of

- a) the interactions between peer DL-entities (DLEs) through the exchange of the fieldbus DLPDUs;
- b) the interactions between a DL-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 Ph-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 which support time-critical communications services within the data-link layer of the OSI or the fieldbus reference models, and which require the ability to interconnect in an open systems interconnection environment.

1.5 Conformance

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

2 Normative references

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

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

IEC 61158-2:2023, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 61158-3-28:2023, *Industrial communication networks – Fieldbus specifications – Part 3-28: Data-link layer service definition – Type 28 elements*

ISO/IEC 7498-1:1994, *Information technology – Open Systems Interconnection – Basic Reference Model – Basic Reference Model: The Basic Model*

ISO/IEC 7498-3:1997, *Information technology – Open Systems Interconnection – Basic Reference Model: Naming and addressing*

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

ISO/IEC 8886:1996, *Information technology – Open Systems Interconnection – Data link service definition*

ISO/IEC/IEEE 8802-3:2021, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet*

3 Terms, definitions, symbols, abbreviated terms and conventions

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

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

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

3.1 Reference model terms and definitions

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

3.1.1	called-DL-address	[ISO/IEC 7498-3]
3.1.2	calling-DL-address	[ISO/IEC 7498-3]
3.1.3	centralized multi-end-point-connection	[ISO/IEC 7498-1]
3.1.4	correspondent (N)-entities	[ISO/IEC 7498-1]
	correspondent DL-entities (N=2)	
	correspondent Ph-entities (N=1)	
3.1.5	Demultiplexing	[ISO/IEC 7498-3]

3.1.6	DL-address	[ISO/IEC 7498-3]
3.1.7	DL-address-mapping	ISO/IEC 7498-1]
3.1.8	DL-connection	[ISO/IEC 7498-1]
3.1.9	DL-connection-end-point	[ISO/IEC 7498-1]
3.1.10	DL-connection-end-point-identifier	[ISO/IEC 7498-1]
3.1.11	DL-connection-mode transmission	[ISO/IEC 7498-1]
3.1.12	DL-connectionless-mode transmission	[ISO/IEC 7498-1]
3.1.13	DL-data-sink	[ISO/IEC 7498-1]
3.1.14	DL-data-source	[ISO/IEC 7498-1]
3.1.15	DL-duplex-transmission	[ISO/IEC 7498-1]
3.1.16	DL-facility	[ISO/IEC 7498-1]
3.1.17	DL-local-view	[ISO/IEC 7498-3]
3.1.18	DL-name	[ISO/IEC 7498-3]
3.1.19	DL-protocol	[ISO/IEC 7498-1]
3.1.20	DL-protocol-connection-identifier	[ISO/IEC 7498-1]
3.1.21	DL-protocol-control-information	[ISO/IEC 7498-1]
3.1.22	DL-protocol-data-unit	[ISO/IEC 7498-1]
3.1.23	DL-protocol-version-identifier	[ISO/IEC 7498-1]
3.1.24	DL-relay	[ISO/IEC 7498-1]
3.1.25	DL-service-connection-identifier	[ISO/IEC 7498-1]
3.1.26	DL-service-data-unit	[ISO/IEC 7498-1]
3.1.27	DL-simplex-transmission	[ISO/IEC 7498-1]
3.1.28	DL-subsystem	[ISO/IEC 7498-1]
3.1.29	DL-user-data	[ISO/IEC 7498-1]
3.1.30	flow control	[ISO/IEC 7498-1]
3.1.31	layer-management	[ISO/IEC 7498-1]
3.1.32	Multiplexing	[ISO/IEC 7498-3]
3.1.33	naming-(addressing)-authority	[ISO/IEC 7498-3]
3.1.34	naming-(addressing)-domain	[ISO/IEC 7498-3]
3.1.35	naming-(addressing)-subdomain	[ISO/IEC 7498-3]
3.1.36	(N)-entity DL-entity Ph-entity	[ISO/IEC 7498-1]
3.1.37	(N)-interface-data-unit DL-service-data-unit (N=2) Ph-interface-data-unit (N=1)	[ISO/IEC 7498-1]
3.1.38	(N)-layer DL-layer (N=2) Ph-layer (N=1)	[ISO/IEC 7498-1]
3.1.39	(N)-service DL-service (N=2) Ph-service (N=1)	[ISO/IEC 7498-1]
3.1.40	(N)-service-access-point DL-service-access-point (N=2) Ph-service-access-point (N=1)	[ISO/IEC 7498-1]

3.1.41	(N)-service-access-point-address	[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 document also makes use of the following terms defined in ISO/IEC 10731 as they apply to the data-link layer:

3.2.1	acceptor
3.2.2	asymmetrical service
3.2.3	confirm (primitive); requestor.deliver (primitive)
3.2.4	deliver (primitive)
3.2.5	DL-confirmed-facility
3.2.6	DL-facility
3.2.7	DL-local-view
3.2.8	DL-mandatory-facility
3.2.9	DL-non-confirmed-facility
3.2.10	DL-provider-initiated-facility
3.2.11	DL-provider-optional-facility
3.2.12	DL-service-primitive; primitive
3.2.13	DL-service-provider
3.2.14	DL-service-user
3.2.15	DLS-user-optional-facility
3.2.16	indication (primitive); acceptor.deliver (primitive)
3.2.17	multi-peer
3.2.18	request (primitive); requestor.submit (primitive)
3.2.19	requestor

**3.2.20 response (primitive);
acceptor.submit (primitive)**

3.2.21 submit (primitive)

3.2.22 symmetrical service

3.3 Common terms and definitions

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

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

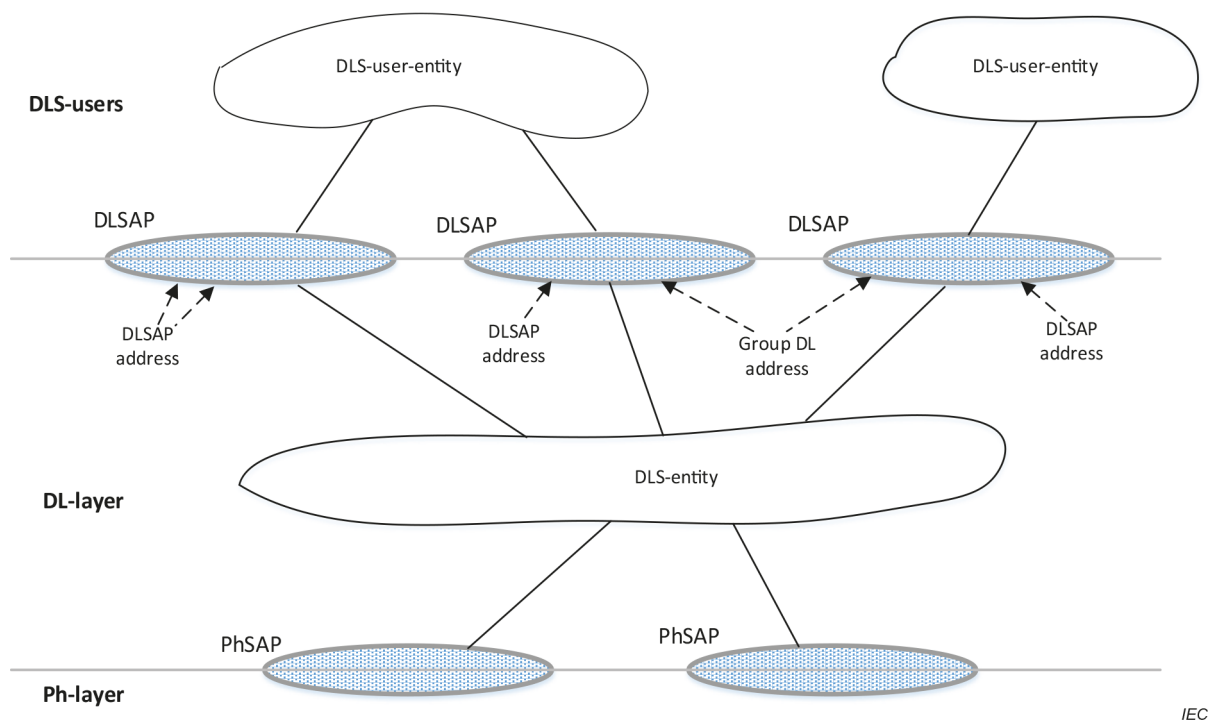
single DL-subnetwork in which any of the connected DLEs may communicate directly, without any intervening DL-relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the period(s) of attempted communication

3.3.2

DLSAP

distinctive point at which DL-services are provided by a single DL-entity to a single higher-layer entity

Note 1 to entry: 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 2 to entry: DLSAPs and PhSAPs are depicted as ovals spanning the boundary between two adjacent layers.

Note 3 to entry: DL-addresses are depicted as designating small gaps (points of access) in the DLL portion of a DLSAP.

Note 4 to entry: A single DL-entity 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 DLS user, or a group DL-address potentially designating multiple DLSAPs where each DLSAP is from a single DLS-user

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

3.3.5**extended link**

DL-subnetwork, consisting of the maximal set of links interconnected by DL-relays, sharing a single DL-name (DL-address) space, in which any of the connected DL-entities may communicate, one with another, either directly or with the assistance of one or more of those intervening DL-relay entities

Note 1 to entry: An extended link may be composed of just a single link.

3.3.6**frame**

denigrated synonym for DLPDU

3.3.7**group DL-address**

DL-address that potentially designates more than one DLSAP within the extended link

Note 1 to entry: A single DL-entity may have multiple group DL-addresses associated with a single DLSAP. A single DL-entity may also have a single group DL-address associated with more than one DLSAP.

3.3.8**node**

single DL-entity as it appears on one local link

3.3.9**receiving DLS-user**

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

Note 1 to entry: A DL-service user can be concurrently both a sending and receiving DLS-user.

3.3.10**sending DLS-user**

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

3.4 Additional Type 28 terms and definitions**3.4.1****control device**

device that controls all field devices for logical operations, timing, calculations, etc.

3.4.2**management node**

device for allocating and managing Type 28 network physical communication resources

3.4.3

terminal node

device in Type 28 network that communicates based on allocated physical communication resources

3.4.4

clock synchronization

clock calibration of the terminal node device

3.4.5

cyclic time

time of cyclic processing of a device or module

3.4.6

RT data

data sensitive to time deterministic requirements

3.4.7

non-RT data

data insensitive to time deterministic requirements

3.4.8

orthogonal frequency division multiplexing (OFDM) symbol

minimum data transmission unit in time domain that include all subcarriers in frequency based on OFDM technology

3.4.9

upper sideband

subcarriers with a frequency range from 16,896 MHz to 32,256 MHz on an OFDM symbol

3.4.10

lower sideband

subcarriers with a frequency range from 1,536 MHz to 16,896 MHz on an OFDM symbol

3.4.11

carrier mode

data transfer mode over available resources made up of OFDM symbols

3.4.12

working mode

OFDM operation in a specific transmission mode, RS coding, convolutional coding, and modulation mode

3.4.13

cyclic frame

signal frames which are processed in a regular and repetitive manner

3.4.14

cyclic symbol

OFDM symbols in signal frames which are processed in a regular and repetitive manner

3.4.15

code block

octet sequence of data interaction between the Type 28 physical layer entity and the Type 28 data-link layer entity

3.4.16**data transmission channel**

logical channel of the Type 28 data-link layer mapped by the determined physical communication resource for transmitting data-link layer data frames

3.4.17**BITMAP**

bitmap format type including Width and Mask_Info information and the length range from 2 octets to 256 octets

Note 1 to entry: See Figure 2.

Note 2 to entry: Width has 1 octet, its value indicates the number of the octets of Mask_Info.

Note 3 to entry: Mask_Info represented by bit. The octet length is Width value and the bit length is Width × 8.

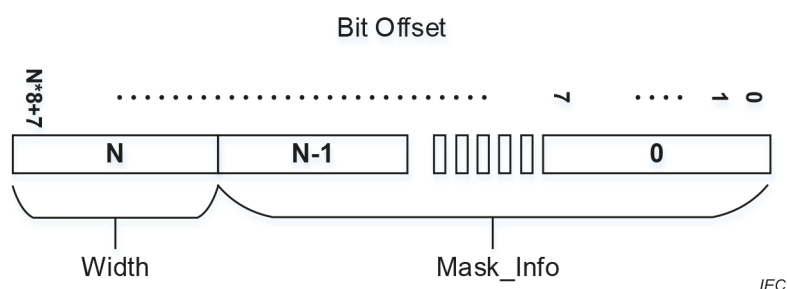


Figure 2 – Bitmap data type diagram

3.5 Additional Type 28 symbols and abbreviations

AL	Application layer
C/S	Client/Server
CLMDTA	Connection-less Mode Data Transmission with Acknowledge
CLMDTNA	Connection-less Mode Data Transmission with No Acknowledge
CLMDTRA	Connection-less Mode Data Transmission with Request and Acknowledge
CLMDTRRNA	Connection-less Mode Data Transmission with Request and Response but No Acknowledge
CMDTA	Connection Mode Data Transmission with Acknowledge
CMDTNA	Connection Mode Data Transmission with No Acknowledge
DL-	Data-link layer (as a prefix)
DLCSS	Data-link clock synchronization service
DLDE	Data-link data entity
DLE	Data-link entity
DLL	Data-link layer
DLM	Data-link management
DLME	Data-link management entity
DLMS	Data-link management service
DLMS-user	Data-link management service user
DLS	Data-link service
DLP	Data-link protocol
DLS-user	Data-link service user
DTC	Data transmission channel
DTS	Data transmission service

DLSDU	Data-link service data unit
DLPDU	Data-link protocol data unit
MAC	Medium access control
MN	Management node
NodeID	Node identifier
nRT	non-Real-Time
OFDM	Orthogonal Frequency Division Multiplexing
PhL	Physical layer
PhL-	Physical layer (as a prefix)
RT	Real-Time
RTA	Real-Time acyclic
RTC	Real-Time cyclic
SAP	Service access point
TM	Transmit mode
TN	Terminal node

4 Overview of the DL-protocol

4.1 DLL protocol architecture

Figure 3 illustrates the position of DLL on the protocol stack architecture of the Type 28.

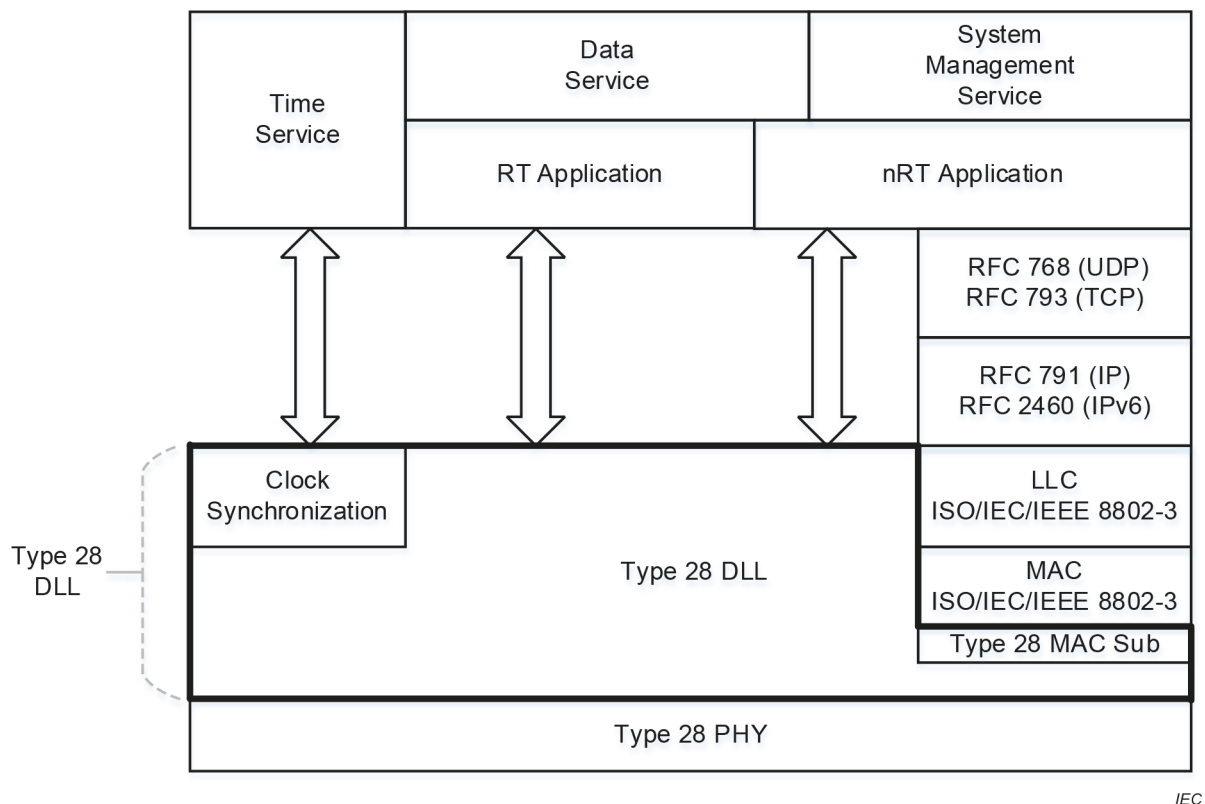
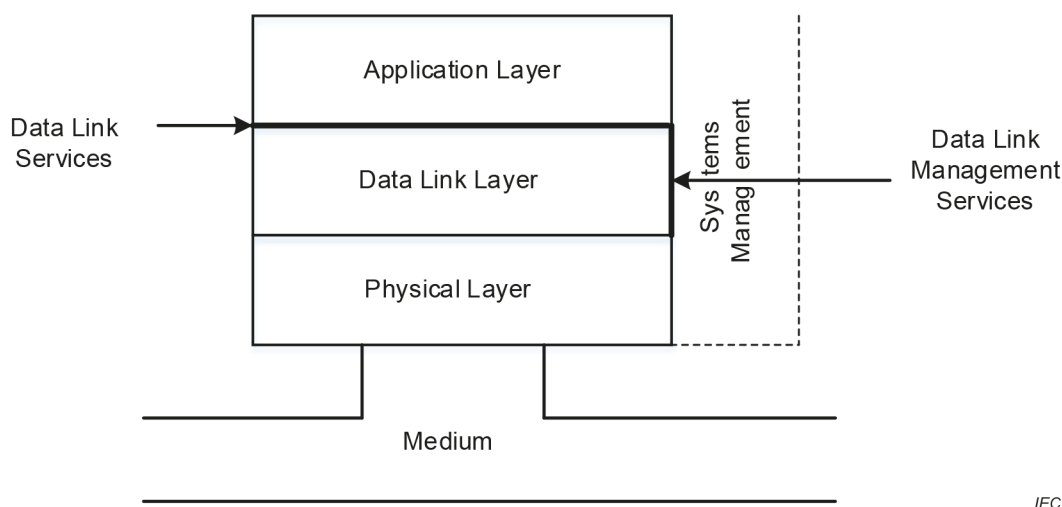


Figure 3 – DLL in Type 28 protocol stack architecture

Type 28 data-link service (DLS) is provided by the Type 28 data-link protocol (DLP) making use of the services available from the Type 28 physical layer (PhL). The DLS characteristics and function defined in this document should be exploited by the higher-level protocol. Type 28 DLL

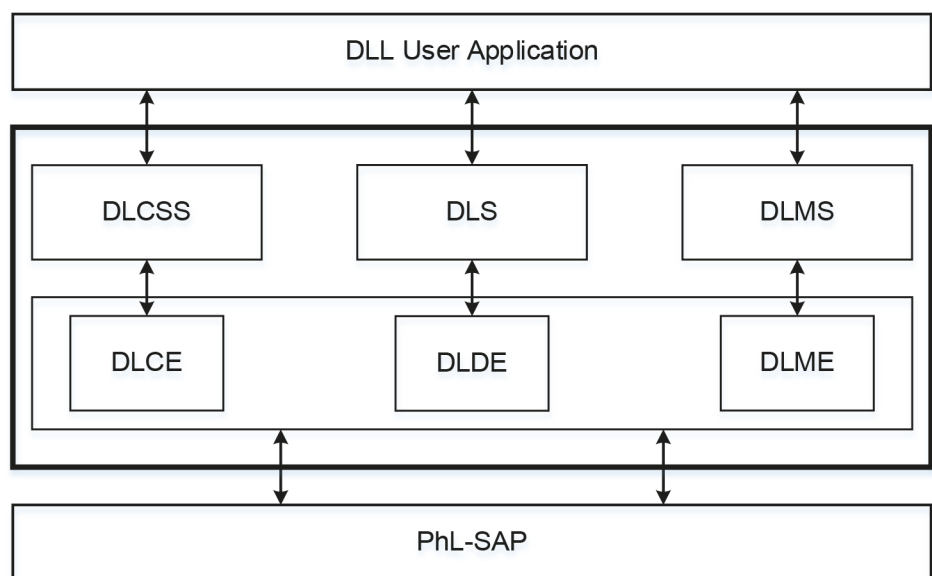
provides data-link management service (DLMS) for system management. The relationship between the standards for the fieldbus DLS, the fieldbus DLP, the fieldbus application protocol and systems management are illustrated in Figure 4.



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Figure 4 – Relationship of the fieldbus DLL to other fieldbus layers and to users of the fieldbus DLS

The services provided by Type 28 DLL to upper users include DLS, DLMS and data-link clock synchronization service (DLCSS). Data-link layer entity (DLE) includes data-link clock entity (DLCE), data-link data entity (DLDE) and data-link management entity (DLME). Based on the communication resource allocation scheme for PhL provided by the Type 28 DLMS, DLS provides data transmission service with different RT levels through connection and connection-less service. Figure 5 shows the Type 28 DLL protocol architecture.



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Figure 5 – Type 28 DLL protocol architecture diagram

DLS: DLS exploits data transmission channel (DTC) established based on PhL OFDM symbol resources to implement the encapsulation and transmission for application data or protocol data. After the state machine of Type 28 DLS is started, DLS provides the connection and the connection-less data transmission service based on DLDE for different RT requirements through different DTCs. These channels should be pre-configured and allocated on demand.

DLMS: DLMS provides system management service, including node joining, node leaving, configuration of network parameters, and establishment, update and release of DTCs, etc. Type 28 DLL configures DLME through DLMS, and then implements the encapsulation and parsing of DLPDU including ISO/IEC/IEEE 8802-3 Ethernet DLPDU in DLDE and the corresponding service function subsets to form the Type 28 mac sublayer as shown in Figure 3.

DLCSS: DLCSS provides the clock synchronization service based on the PhL service access point (PhL-SAP), defining delay measurement, clock synchronization and clock interrupt services.

4.2 DLL working mechanism

4.2.1 Node

Type 28 network contains at least one management node (MN) and 0 to 253 terminal nodes (TN). Only one active MN is allowed in the network. The MN should configure all available nodes in the network and manage node access to the network. The TN works normally after it is authorised by MN. The TN sends the data after the MN confirms the available DTC resources.

Each TN in Type 28 network supports both static configuration and automatic discovery.

4.2.2 Addressing

Nodes in Type 28 network are addressed on DLL by device NodeID. There are three different types of NodeID: unicast, broadcast and multicast.

Each node (MN or TN) has a unique node identifier (NodeID) in a Type 28 network. NodeID 0 should only be assigned to the MN. NodeID 1 to 253 can be used as the address of TNs or multicast group.

The NodeID address assignment of Type 28 DLL is shown in Table 1. The unicast address of Type 28 network should be globally unique.

Table 1 – NodeID address assignment of Type 28 DLL

NodeID	NodeID name	Description
0	DLL_NODEID_MN	MN
1 to 253		Normal TN or Multicast group NodeID
254		Reserved
255	DLL_NODEID_BROADCAST	Type 28 broadcast

The NodeID should be assigned by the MN when accessing the network. The source address and the destination address should be identified by NodeID when the DLPDU is transmitted on the network. The NodeID has one-to-one mapping relationship with the device's global unique MAC address in Type 28 network that supports ISO/IEC/IEEE 8802-3 Ethernet. When the Type 28 network carries the service of ISO/IEC/IEEE 8802-3, the MN maintains the mapping table between NodeID and the MAC address of ISO/IEC/IEEE 8802-3 in real time, and broadcasts it to all TNs. The NodeID and MAC address mapping table is described in Table 2.

Table 2 – NodeID and MAC address mapping table

Item	Description
NodeID	The NodeID address of the device, with a valid range from 0 to 253
STATE	State of table entry, 0 indicates valid and 1 indicates invalid
MAC-ADDR	The MAC (defined in ISO/IEC/IEEE 8802-3) address of the corresponding node

Annex A shows an example of the mapping of NodeID and MAC address stored on a TN of the Type 28 network.

4.2.3 Multicast

Type 28 DLP specification uses multicast address to implement the data transmission between single node and multiple nodes. The range of multicast types NodeID is from 238 to 253, which supports up to 16 multicast groups. The assignment of multicast type NodeID starts from 253 in descending order. The multicast group mapping table is stored on each node. The members of the multicast group mapping table are described in Table 3.

Table 3 – Members of multicast group mapping table

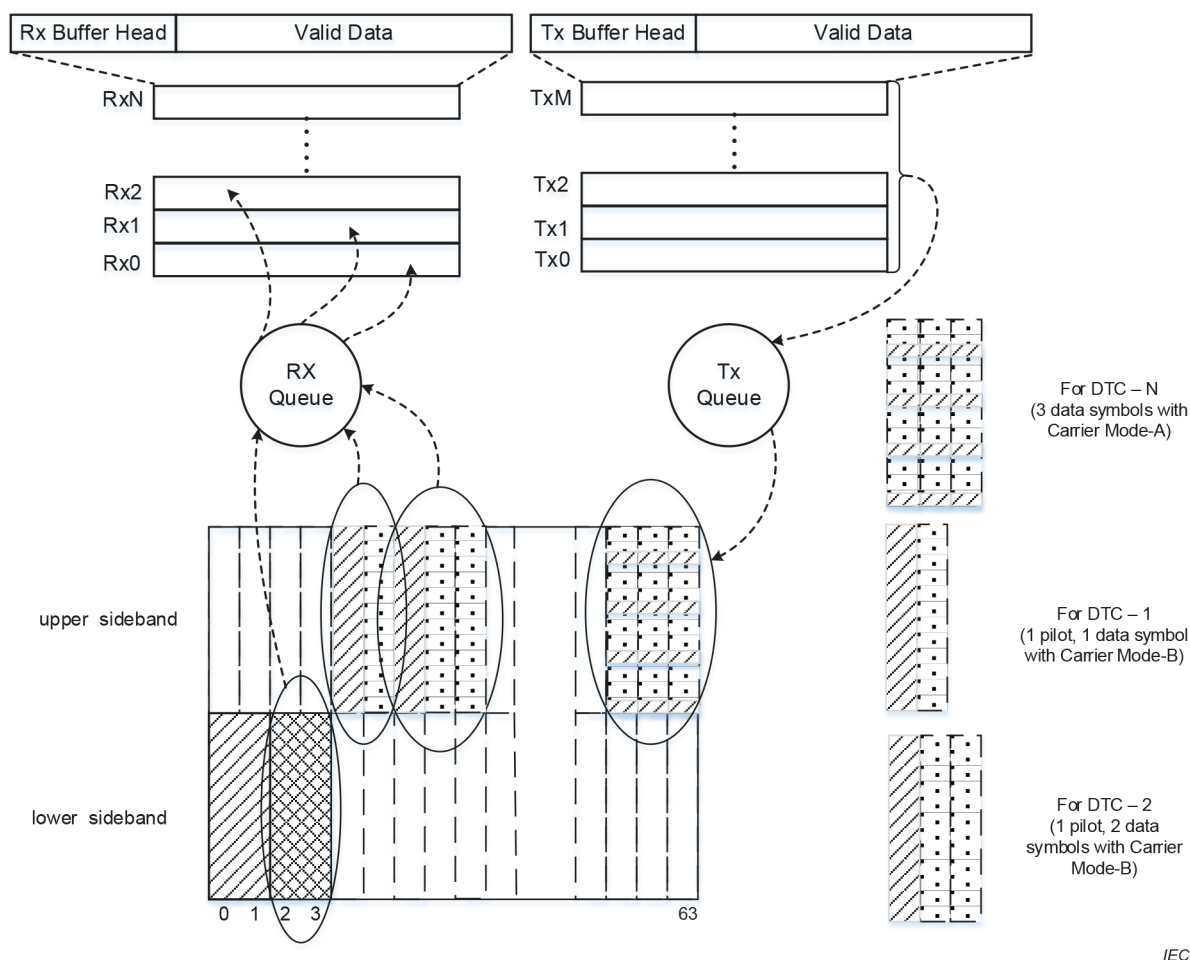
Item	Description
Multicast index	Multicast index starting from 1
Multicast ID	Multicast type NodeID specified in Table 1
Member mask	Multicast member represented by a mask mode, where the mask bit corresponds to the NodeID of the member node

The establishment of multicast group mapping table supports static configuration and dynamic configuration. The static configured multicast mapping table information is sent by the MN to all TNs. The MN determines whether the corresponding TN joins the corresponding multicast group as a member of the multicast group successfully through the response information of the member TN. The dynamic configured multicast group mapping table is applied by the TN according to the requirements of DTC, and the MN should assign the dynamic multicast address after receiving the request. The assignment information is sent to the requesting TN to create or update the corresponding multicast group mapping table.

Annex B shows an example for the Type 28 multicast group working mechanism.

4.2.4 Resource mapping and scheduling

DTC is a logical channel for transmitting DLPDUs on DLL, and it is mapped with the determined PhL communication resource. According to the bus configuration, the node receives the data from determined DTC. If the data received meets the requirements of the node configuration, the data shall be stored in the packet receiving buffer queue of DLL based on the scheduled result of receiving packet queue and will be processed by Application Layer (AL) user. The data to be sent in the packet transmitting buffer queue of DLL should be taken out based on the scheduled result of the sending message queue, and be scheduled to the requested DTC. The PhL sends out the data on the corresponding symbol resource with setting mode. Figure 6 shows the resource mapping between DLL and PhL.



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Figure 6 – Resource mapping between DLL and PhL

Description:

- Rx Queue: Receiving message queue
- Tx Queue: Transmitting message queue
- Rx0, Rx1, Rx2....RxN: Packet receiving buffer queue
- Tx0, Tx1, Tx2....TxM: Packet transmitting buffer queue
- Rx Buffer Head: Head information of packet receiving buffer queue that contains data type, queue number, priority, etc.
- Tx Buffer Head: Head information of packet transmitting buffer queue that contains data type, queue number, priority, etc.
- Valid Data: Valid data that has been received or will be sent

When the DLE receives the packets, it puts the parsed data into packet receiving buffer queue according to the data type by scheduling the receiving message queue; and when sending packets, DLE puts the data to be sent into the corresponding packet transmitting buffer queue according to the different data types. The valid data is sent out based on the symbol resource of PhL by scheduling the transmitting message queue. In DLL, the packet buffer resources are mapped to the corresponding physical resources by the scheduling receiving/transmitting message queue, and the determined data buffer resources are processed on the determined physical resources. This scheduling relationship for receiving message queues and transmitting message queues is shown in Figure 7.

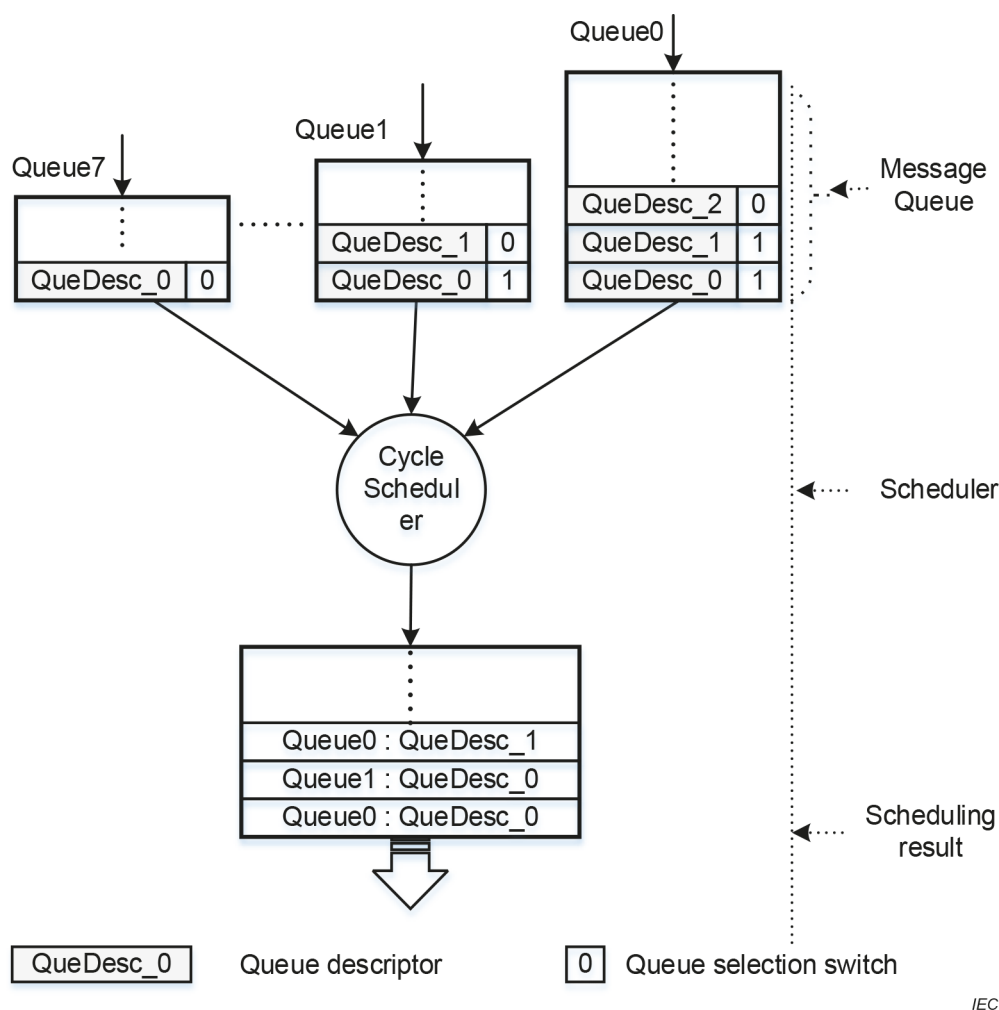


Figure 7 – DLL resource mapping message queue scheduling diagram

Description:

- Queue descriptor: including the data address, the length and the corresponding queue priority of the buffer.
- Queue selection switch: The 1 indicates that the corresponding queue is selected, the 0 indicates that the corresponding queue is not selected, and the corresponding switch value reset to 0 after being scheduled.
- Scheduler: the cyclic scheduler based on priority, cyclic scheduling of message queues and output the selected queue descriptor information.
- Scheduling result: Queue descriptor information that is output to PhL or DLL.
- Queue number and queue depth: the system supports 8 message queues; each message queue depth can be configured to be different.

5 DLPDU structure

5.1 Universal DLPDU structure

Type 28 DLPDUs have a general structure, as shown in Figure 8.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3 to n	PAYLOAD							
n+1 to n+2	CRC							

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Figure 8 – Universal DLPDU structure

Each field is defined as:

- TYPE: 1 octet, the type of DLPDU, supports up to 256 different types. The type value 0x00 to 0x1F is a protocol control DLPDU reserved by the system, including:
 - TYPE = 0x00/0x01: Reserved for equipment manufacturers;
 - TYPE = 0x02: Basic configuration DLPDU;
 - TYPE = 0x03: Address allocation DLPDU;
 - TYPE = 0x04: Multicast address allocation DLPDU;
 - TYPE = 0x05: RT resource allocation DLPDU;
 - TYPE = 0x06: nRT resource allocation DLPDU;
 - TYPE = 0x07: Access notification DLPDU;
 - TYPE = 0x08: Resource request DLPDU;
 - TYPE = 0x09: Resource release DLPDU;
 - TYPE = 0x0A: Status query DLPDU;
 - TYPE = 0x0B: Status response DLPDU;
 - TYPE = 0x0C: Announcement DLPDU;
 - TYPE = 0x10: Clock synchronization DLPDU;
 - TYPE = 0x0D to 0x0F, 0x11 to 0x1F: Reserved
 - TYPE with 0x20 to 0xFF belong to the ordinary DLPDU defined by the user.

TYPE field not only distinguishes different DLPDU types, but also represents the higher priority of the DLPDU with smaller value of TYPE.

- Fragment_No: 4 bits, packet fragment sequence number; when field is 0, it means that the packet is no fragment, and when the field is not 0, it means the sequence number of the packet fragment, and the value 1 means the last piece of packet fragment.
- LEN: 12 bits, the length of a DLPDU, unit is octet, indicating that the DLPDU length from the start of the TYPE field to the beginning of the CRC. A valid DLPDU length range supported by the DLP is 4 to 2 048 octets.
- PAYLOAD: The data payload of a DLPDU whose length is related to type. For different types of DLPDUs, the data with different structures and lengths are defined in the payload section.
- CRC: 2 octets of CRC-16 check bit, the CRC of DLPDU automatically calculated and valued by the hardware. The field will not be described again in this document.

5.2 Basic configuration DLPDU

In the initialization phase of Type 28 network, the MN broadcasts the basic configuration to all the TNs in the network to ensure consistency of the basic configuration, and the protocol state machine should be negotiated in the next step. This type of DLPDU is sent once per physical communication period, and frame number alignment is achieved synchronously in the network.

The basic configuration includes: working mode, PhL frame format configuration, node random access resource allocation, NodeID and multicast address, access mode, and PhL frame sequence number alignment in initialization phase. The DLPDU structure is shown in Figure 9.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3	VER							
4	Reserved							
5 to 10	FrameID_Seq							
11 to 24	COMM_Cfg							
25	Reserved							
26 to 27	CRC							

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Figure 9 – Basic configuration DLPDU structure

Each field is defined as:

- TYPE: 1 octet, set as 0x02 for basic configuration DLPDU type.
- Fragment_No: 4 bits, Packet fragment sequence number, refer to universal DLPDU structure description.
- LEN: 12 bits, the length of DLPDU octets from the start of the TYPE field to the beginning of the CRC field, refer to universal DLPDU structure description.
- VER: 1 octet, Version number of Type 28 protocol.
- Reserved: The 4th octet and the 25th octet are reserved fields.
- FrameID_Seq: 6 octets, MN to the physical frame relative count, and the valid value range is 0 to $(2^{44} - 1)$ for the user node alignment count. This number is unique for each cycle of the current network.
- COMM_Cfg, Equal to or greater than 14 octets, general configuration block information for the network, as shown in Figure 10.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TransmitMode				Default_USB_WorkMode			
1	Default_USB_WorkMode		Default_LSB_WorkMode					
2	AccessStatus				Frame_Fmt			
3	Ucn_Num							
4	Mcn_Num							
5	DownStream_Symbol_Num							
6	Cycle_Frame_Num				App_Mode		Reserved	
7	R_RT_Attr							
8	R_RT_Attr				R_Cycle_Symbol_Len			
9	R_Cycle_Symbol_Len							
10	R_Band_Flag		R_Band_Mode					
11	R_Symbol_Start							
12	R_Symbol_Start				R_Symbol_Num			
13	R_Symbol_Num							

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Figure 10 – General configuration block structure

- TransmitMode: 4 bits, system TM, valid value is 0, 1, 2, 3.
- Default_USB_WorkMode: 6 bits, default working mode of upper sideband (refer to IEC 61158-2, 8.6.2.2.6).
- Default_LSB_WorkMode: 6 bits, default working mode of lower sideband (refer to IEC 61158-2, 8.6.2.2.6).
- AccessStats: 4 bits, access status.
- Frame_Fmt: 4 bits, PhL frame format, default 0x0 identifies a physical signal frame with 64 symbols.
- Ucn_Num: 1 octet, total number of NodeID including MN.
- Mcn_Num: 1 octet, the total number of multicast group NodeID, the maximum number of multicasts is 16, and the default is 0.
- DownStream_Symbol_Num: 1 octet, the number of symbols of the downlink subframe, with a default value of 2. This field is identical to IEC 61158-3-28, Clause 5.
- Cycle_Frame_Num: 4 bits, the number of cycles of cyclic frame. This field is identical to IEC 61158-3-28, Clause 5.
- App_Mode: 2 bits, Access mode configuration, 0x0: fixed algorithm access mode; 0x1: user algorithm access mode.
- Reserved: 2 bits, reserved field.
- R_Cycle_Symbol_Len: 12 bits, cycle length of cyclic symbol of random access symbol. This field is identical to IEC 61158-3-28, Clause 5.
- R_RT_Attr: 12 bits, RT attributes of random access symbols. This field is identical to IEC 61158-3-28, Clause 5.
- R_Band_Flag: 2 bits, the sideband occupation identification of the random access symbol. This field is identical to IEC 61158-3-28, Clause 5.
- R_Band_Mode: 6 bits, the sideband occupation working mode of the random access symbol. This field is identical to IEC 61158-3-28, Clause 5.
- R_Symbol_Start: 12 bits, Random access symbol start number. This field is identical to IEC 61158-3-28, Clause 5.
- R_Symbol_Num: 12 bits, Number of random access symbols. This field is identical to IEC 61158-3-28, Clause 5

5.3 Address assignment DLPDU

The address assignment DLPDU is used to realize the NodeID assignment function, the MN broadcasts the DLPDU including the available NodeID resource to all TNs in the network. The TN self-configures the allocated NodeID, and realizes the node identification and addressing based on NodeID.

The structure of the address assignment DLPDU is shown in Figure 11.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3 to 4	Start_NodeID							
5	Ucn_Num							
6 to 11	MAC_Addr_1							
...								
(6*n) to (6*n+5)	MAC_Addr_n							
(6*n+6) to (6*n+7)	CRC							

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Figure 11 – Address allocation DLPDU structure

Each field is defined as:

- TYPE: 1 octet, set as 0x03 for NodeID address allocation DLPDU.
- Fragment_No: 4 bits, Packet fragment sequence number, refer to universal DLPDU structure description.
- LEN: 12 bits, DLPDU length, the length of DLPDU octets from the start of the TYPE field to the beginning of the CRC field, refer to universal DLPDU structure description. The allocation information of address resources can be processed in batches after allocating the consecutive NodeID sections.
- Start_NodeID: 2 octets, Start NodeID of the NodeID resource allocation section.
- Ucn_Num: 1 octet, the length of the NodeID resource allocation section, that is, the number of NodeID that the section contains.
- MAC_Addr_1 to MAC_Addr_n: MAC addresses list with Ucn_Num nodes initially assigned by Start_NodeID. Each consecutive 6 octets from the 6th octet as a valid MAC address for a total of Ucn_Num MAC addresses.

5.4 Multicast assignment DLPDU

Multicast address assignment function is used to implement multicast services in the network. In the initialization phase of the network, the MN broadcasts the DLPDU including the multicast address assignment results to all nodes.

The structure of the multicast assignment DLPDU is shown in Figure 12.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3 to 4	MC_NodeID							
5	Group_Nodes_Num							
6	Group_Nodes_Mem							
...	...							
37	Group_Nodes_Mem							
38 to 39	Reserved							
40 to 41	CRC							

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Figure 12 – Multicast assignment DLPDU structure

Each field is defined as:

- TYPE: 1 octet, set as 0x04, multicast groups address allocation DLPDUs.
- Fragment_No: 4 bits, packet fragment sequence number, refer to universal DLPDU structure description.
- LEN: 12 bits, refer to universal DLPDU structure description.
- MC_NodeID: 1 octet, the corresponding multicast group NodeID, which broadcasts the address assignment result of one multicast group at a time.
- Group_Nodes_Num: 1 octet, the number of one MC_NodeID multicast group members.
- Group_Nodes_Mem: 32 octets, based on the BITMAP format, the corresponding bit is 0 which indicates that the corresponding NodeID node is not in the current multicast group, and the 1 indicates the corresponding NodeID node is in the current multicast group.
- Reserved: 1 octet, reserved field.

5.5 Resource allocation DLPDU

The data processed in the DLL is divided into RT data and nRT data (see 6.1.2), and the corresponding resource allocation can be configured before the network starts, the MN sends to all nodes in the network through the bandwidth resource allocation DLPDU to complete the configuration and mapping of the related resources in the initialization access configuration phase. Or during the operation of the system, the TN can apply for the resources dynamically from the MN according to the service requirement, and the MN can assign the corresponding resources to this node to carry on the data transmission processing. The resource allocation DLPDUs for RT and nRT resources have the same format, except that the corresponding type values are different. For RT resource allocation DLPDUs, TYPE value is 0x05, nRT resource allocation DLPDUs, TYPE value is 0x06, and the corresponding DLPDU structure is shown in Figure 13.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3 to 4	Channel_ID							
5	Sequence_No							
6 to 7	Dst_NodeID							
8	Service_Type							
9	RxTx_Attr		RT_Attr					
10	RT_Attr						Res_Flag	
11	Cycle_Symbol_Len							
12	Cycle_Symbol_Len				Reserved1			
13	Band_Flag_1		Band_Mode_1					
14	Symbol_Start_1							
15	Symbol_Start_1				Symbol_Num_1			
16	Symbol_Num_1							
17	Band_Flag_2		Band_Mode_2					
18	Symbol_Start_2							
19	Symbol_Start_2				Symbol_Num_2			
20	Symbol_Num_2							
21	Reserved2							
22 to 23	CRC							

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Figure 13 – Resource allocation DLPDU structure

Each field is defined as:

- TYPE: 1 octet for resource allocation DLPDU type:
 - 0x05: RT resource allocation DLPDU;
 - 0x06: nRT resource allocation DLPDUs.
- Fragment_No: 4 bits, packet fragment sequence number, refer to universal DLPDU structure description.
- LEN: 12 bits, Refer to universal DLPDU structure description.
- Channel_ID: 2 octets, the corresponding connection resource channel ID number.
- Sequence_No: 1 octet, resource allocation frame sequence number, when there are more than two channel resource blocks at the same DTC Channel_ID, multiple resource allocation frames should be used for allocation.
- Dst_NodeID: 2 octets; the NodeID value of the node to which the resource channel is assigned.
- Service_Type: 1 octet; the service data type used by the resource channel. This field is identical to IEC 61158-3-28, Clause 5.
- RxTx_Attr: 2 bits, bus data processing mode on the channel resources, 0x0 for read and 0x1 for write. This field is identical to IEC 61158-3-28, Clause 5.
- RT_Attr: 12 bits, the RT attribute of the resource channel. This field is identical to IEC 61158-3-28, Clause 5.

- Res_Flag: 2 bits, indicating whether the first and second groups of symbol resource block configurations are valid or not, bit 0 indicates the first group configuration and bit 1 indicates the second group configuration; if the corresponding bit is set to 0x1, the group configuration is valid.
- Cycle_Symbol_Len: 12 bits; flag the cycle length of the symbol and this field is identical to IEC 61158-3-28, Clause 5.
- Band_Flag1 - 2: 2 bits, indicating the upper and lower sideband of symbol based on bit, as specified in IEC 61158-3-28, Clause 5.
- Band_Mode_1 - 2: 6 bits, the working mode of the allocated first and second groups of symbol resources, as specified in IEC 61158-3-28, Clause 5.
- Symbol_Start_1 - 2: 12 bits, start symbol number of the allocated first and second groups of symbol resources; as specified in IEC 61158-3-28, Clause 5.
- Symbol_Num_1 - 2: 12 bits, the number of symbols of the allocated first and second groups of symbol resources; as specified in IEC 61158-3-28, Clause 5.
- Reserved1: 4 bits, reserved field.
- Reserved2: 1 octet, reserved field.

5.6 Access notification DLPDU

When TN starts up, it broadcasts the access notification DLPDU in the network through the allocated resource. The content of the transmission includes destination node NodeID, own NodeID, the status of this node and the MAC address information, and the numbers of notification DLPDUs received from different NodeID. The access notification DLPDU is the basis for the communication between nodes of the entire network. The access of the TN is acquired by the MN in the network in real time.

The access notification DLPDU structure is shown in Figure 14.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3 to 4	Dst_NodeID							
5 to 6	Src_NodeID							
7	Nodes_Num							
8 to 13	Mac_Addr							
14	Node_Status							
15	Reserved							
16 to 17	CRC							

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Figure 14 – Access notification DLPDU structure

Each field is defined as:

- TYPE: 1 octet, set as 0x07 for access notification DLPDU.
- Fragment_No: 4 bits, packet fragment sequence number, refer to universal DLPDU structure description.
- LEN: 12 bits, refer to universal DLPDU structure description.
- Dst_NodeID: 2 octets, destination node address NodeID value.
- Src_NodeID: 2 octets, source node address NodeID value.

- Nodes_Num: 1 octet, the numbers of access notification DLPDUs received from different nodes correctly.
- Mac_Addr: 6 octets, identify the MAC address of the source node.
- Node_Status: 1 octet, the running state of this node, 0x00 is initialization phase, 0x01 is ready; other values reserved; as specified in IEC 61158-3-28, Clause 5.
- Reserved: 1 octet, reserved field.

5.7 Resource application DLPDU

Before the fieldbus network works, the MN transmits the physical symbol resources allocation result to each TN in the network. After the network is activated, the TN dynamically applies for nRT resources to process the sending and receiving of the corresponding nRT data (see 6.1.2). For the MN, the dynamic application should be completed locally; for the TN, the application information should be encapsulated as a dynamic resource application DLPDU and sent to the MN for allocation. If the TN accesses the network successfully, the transmission is processed based on the corresponding resource. If not successfully so, the corresponding nRT data will be discarded and the DLS-user should be notified.

The structure of the resource application DLPDU is shown in Figure 15.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3 to 4	Dst_NodeID							
5 to 6	Src_NodeID							
7 to 8	Channel_ID							
9	Service_Type							
10 to 11	APPBw							
12 to 13	LoopTime							
14 to 15	Reserved							
16 to 17	CRC							

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Figure 15 – Resource application DLPDU structure

Each field is defined as:

- TYPE: 1 octet, set as 0x08 for dynamic resource application DLPDU.
- Fragment_No: 4 bits, packet fragment sequence number, refer to universal DLPDU structure description.
- LEN: 12 bits, refer to universal DLPDU structure description, the resource request DLPDU length is fixed to 18.
- Dst_NodeID: 2 octets, Destination node address NodeID value, default is MN's NodeID.
- Src_NodeID: 2 octets, Source node address NodeID value for resource application, default is the NodeID of this node
- Channel_ID: 2 octets, the corresponding resource channel ID number; the ID number is a full F invalid value when the user applied for the first time.
- Service_Type: 1 octet, the service data type values that dynamically request resources to be loaded. This field is identical to IEC 61158-3-28, Clause 5.
- APPBW: 2 octets, the size of the amount of service data that shall be applied for resource to be loaded and the unit is octet. This field is identical to IEC 61158-3-28, Clause 5.

- LoopTime: 2 octets, the cycle time to apply for resource carrying data and the unit is μs . This field is identical to IEC 61158-3-28, Clause 5.
- Reserved: 2 octets, reserved field.

5.8 Resource release DLPDU

The resource dynamically requested by the TN can be used within the time of application. When the number of times and time of application meet the set threshold, the resource should be automatically released and recycled by the system. In some cases, the TN can proactively release the requested resource by sending the resource release DLPDU to the MN.

The structure of the resource release DLPDU is shown in Figure 16.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3 to 4	Dst_NodeID							
5 to 6	Src_NodeID							
7 to 8	Channel_ID							
9	Sequence_No							
10	Service_Type							
11	Reserved							
12 to 13	CRC							

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Figure 16 – Resource release DLPDU structure

Each field is defined as:

- TYPE: 1 octet, set as 0x09 for dynamic resource request DLPDU.
- Fragment_No: 4 bits, packet fragment sequence number, refer to universal DLPDU structure description.
- LEN: 12 bits, refer to universal DLPDU structure description.
- Dst_NodeID: 2 octets, NodeID value corresponds to the destination node address for the release service.
- Src_NodeID: 2 octets, NodeID value corresponds to the source node address for the release service.
- Channel_ID: 2 octets, the released resource channel ID number.
- Sequence_No: 1 octet, resource allocation frame number. If the field is 0x00, all symbol resources in the channel should be deleted.
- Service_Type: 1 octet, based on the service data type values loaded by the released resource channel. This field is identical to IEC 61158-3-28, Clause 5.
- Reserved: 1 octet, reserved field.

5.9 Status query DLPDU

The maintenance service mainly completes the specific function by the status query DLPDU and the status response DLPDU, and the maintenance service function can refer to the description of the command parameter (as specified in IEC 61158-3-28, Clause 5); When the MN detects that no DLPDU has been sent by a specified node within a certain period of time or when a new node randomly accesses, the MN broadcasts the status query DLPDU, and the normal nodes should respond with the access notification DLPDU. The node that runs abnormally or has been offline should not respond.

The structure of the status query DLPDU is shown in Figure 17.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3 to 4	Dst_NodeID							
5 to 6	Src_NodeID							
7	Command							
8 to 9	CRC							

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Figure 17 – Status query DLPDU structure

Each field is defined as:

- TYPE: 1 octet, set as 0x0A for status query DLPDU.
- Fragment_No: 4 bits, packet fragment sequence number, refer to universal DLPDU structure description.
- LEN: 12 bits, refer to universal DLPDU structure description.
- Dst_NodeID: 1 octet, destination node address NodeID value for query.
- Src_NodeID: 1 octet, source node address NodeID value for query.
- Command: 1 octet, the command word for query operation at the destination node is identical with IEC 61158-3-28, 5.3.

5.10 Status response DLPDU

The destination node of the status query decides whether or not to respond according to the command word in the status query DLPDU, and sends the status response DLPDU to the status query source node. The status response DLPDU contains the result of the query and the status information.

The structure of the status response DLPDU is shown in Figure 18.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3 to 4	Dst_NodeID							
5 to 6	Src_NodeID							
7	Command							
8	NodeState							
9 to 10	ChannelCnt							
11 to 14	WarnCnt							
15 to 18	ErrCode							
19	Reserved							
20 to 21	CRC							

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Figure 18 – Status response DLPDU structure

Each field is defined as:

- TYPE: 1 octet, set as 0x0B for status query DLPDU.
- Fragment_No: 4 bits, packet fragment sequence number, refer to universal DLPDU structure description.
- LEN: 12 bits, refer to universal DLPDU structure description.
- Dst_NodeID: 2 octets, NodeID value of destination node address for response.
- Src_NodeID: 2 octets, NodeID value of source node address for response.
- Command: 1 octet, response command values that identify the response source node. This field is identical to IEC 61158-3-28, Clause 5.
- NodeState: 1 octet, the status of the response source node. This field is identical to IEC 61158-3-28, Clause 5.
- ChannelCnt: 2 octets, the number of DTCs that are being used by the source node. This field is identical to IEC 61158-3-28, Clause 5.
- WarnCnt: 4 octets, the number of alerts generated by the response source node. This field is identical to IEC 61158-3-28, Clause 5.
- ErrCode: 4 octets, the last error code on the reply source node. This field is identical to IEC 61158-3-28, Clause 5.
- Reserved: 1 octet, reserved field.

5.11 Announcement DLPDU

During link maintenance, the MN sends the announcement DLPDU to the fieldbus network, and the TN confirms whether the local configuration is consistent with the MN based on the DLPDU. The announcement DLPDU structure is shown in Figure 19.

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	TYPE							
1	Fragment_No				LEN			
2	LEN							
3 to 4	Dst_NodeID							
5 to 6	Src_NodeID							
7	Command							
8	Ucn_Num							
9	Mcn_Num							
10	LaunchMode							
11	Default_USB_WorkMode						Default_LSB_WorkMode	
12	Default_LSB_WorkMode				Cycle_Frame_Num			
13	R_RT_Attr							
14	R_RT_Attr				R_Cycle_Symbol_Len			
15	R_Cycle_Symbol_Len							
16	R_Band_Flag		R_Band_Mode					
17	R_Symbol_Start							
18	R_Symbol_Start				R_Symbol_Num			
19	R_Symbol_Num							
20 to 21	CRC							

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Figure 19 – Announcement DLPDU structure