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Industrial communication networks – Fieldbus specifications – Part 4-17: Data-link layer protocol specification – Type 17 elements

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-17: Data-link layer protocol specification – Type 17 elements

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PCT Application No. PCT/JP2004/011537 [YEC] Communication control method

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International Standard IEC 61158-4-17 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This first edition and its companion parts of the IEC 61158-4 subseries cancel and replace IEC 61158-4:2003. This edition of this part constitutes a technical addition. This part and its Type 17 companion parts also cancel and replace IEC/PAS 62405, published in 2005.

This edition of IEC 61158-4 includes the following significant changes from the previous edition:

a) deletion of the former Type 6 fieldbus, and the placeholder for a Type 5 fieldbus data link layer, for lack of market relevance;

b) addition of new types of fieldbuses;

c) division of this part into multiple parts numbered -4-1, -4-2, …, -4-19.

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

FDIS	Report on voting
65C/474/FDIS	65C/485/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.

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

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn;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.

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

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.

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-17: Data-link layer protocol specification – Type 17 elements

1 Scope

1.1 General

The data-link layer provides basic time-critical messaging communications between devices in an automation environment.

This protocol provides communication opportunities to all participating data-link entities

a) in a cyclic asynchronous manner, sequentially to each of those data-link entities, and

b) in a synchronous manner, either cyclically or acyclically, according to a pre-established schedule.

The specified protocol also provides means of changing the set of participating data-link entities and of modifying the set of scheduled communications opportunities. When the set of scheduled communications opportunities is null, the distribution of communication opportunities to the participating data-link entities is completely asynchronous.

Thus this protocol can be characterized as one which provides access asynchronously but with a synchronous overlay.

1.2 Specifications

This standard 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 standard, 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 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 fieldbus reference models, and which 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-critical 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 reference

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

IEC 61158-3-17, *Industrial communication networks – Fieldbus specifications – Part 3-17: Data-link layer service definition – Type 17 elements*

ISO/IEC 7498 (all parts), *Information technology – Open Systems Interconnection – Basic Reference Model*

ISO/IEC 8802-3, *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, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*

IEEE Std 802.3ab, *Information technology – Telecommunications and information exchange between systems - Local and metropolitan area networks – Specific requirements – Supplement to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and physical layer specifications – Physical layer parameters and specifications for 1000 Mb/s operation over 4-pair of category 5 balanced copper cabling, type 1000BASE-T*

Internet Engineering Task Force (IETF), *Request for Comments (RFC):*

RFC 768	*User Datagram Protocol* (available at <http://www.ietf.org/rfc/rfc0768.txt>)
RFC 791	*Internet Protocol* (available at <http://www.ietf.org/rfc/rfc0791.txt>)
RFC 792	*Internet Control Message Protocol* (available at <http://www.ietf.org/rfc/rfc0792.txt>)
RFC 826	*Ethernet Address Resolution Protocol* (available at <http://www.ietf.org/rfc/rfc0826.txt>)
RFC 894	A standard for the Transmission of IP Datagrams over Ethernet Networks (available at <http://www.ietf.org/rfc/rfc0894.txt>)
RFC 1112	*Host Extensions for IP Multicasting* (available at <http://www.ietf.org/rfc/rfc1112.txt>)
RFC 2236	*Internet Group Management Protocol Version 2* (available at <http://www.ietf.org/rfc/rfc2236.txt>)

3 Definitions

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

3.1 Terms and definitions

3.1.1 ISO/IEC 10731 terms

a) (N)-connection

b) (N)-entity

c) (N)-layer

d) (N)-service
e) (N)-service-access-point
f) confirm (primitive)
g) deliver (primitive)
h) indication (primitive)
i) request (primitive)
j) response (primitive)

3.1.2 Other terms and definitions

3.1.2.1
bridge
intermediate equipment that connects two or more segments using a Data Link layer relay function

3.1.2.2
domain
part of the RTE network consisting of one or two subnetwork(s)

NOTE Two subnetworks are required to compose a dual-redundant RTE network, and each end node in the domain is connected to both of the subnetworks.

3.1.2.3
domain master
station which performs diagnosis of routes to all other domains, distribution of network time to nodes inside the domain, acquisition of absolute time from the network time master and notification of status of the domain

3.1.2.4
domain number
numeric identifier which indicates a domain

3.1.2.5
external bridge
bridge to which neither internal bridges nor RTE stations are connected directly

3.1.2.6
interface port
physical connection point of an end node, which has an independent DL-address

3.1.2.7
internal bridge
bridge to which no routers, external bridges or nodes non-compliant with this specification are connected directly

3.1.2.8
junction bridge
bridge to which at least one router, external bridge or node non-compliant with this specification, and to which at least one internal bridge or RTE station is connected

3.1.2.9
link
physical communication channel between two nodes

3.1.2.10
network time master
station which distributes network time to domain masters

3.1.2.11
non-redundant interface node
node whch has a single interface port

3.1.2.12
non-redundant station
station that consists of a single end node

NOTE “non-redundant station” is synonymous with “end node”.

3.1.2.13
path
logical communication channel between two nodes, which consists of one or two link(s)

3.1.2.14
redundant interface node
node with two interface ports one of which is connected to a primary network, while the other is connected to a secondary network

3.1.2.15
redundant station
station that consists of a pair of end nodes

NOTE Each end node of a redundant station has the same station number, but has a different DL-address.

3.1.2.16
route
logical communication channel between two communication end nodes

3.1.2.17
router
intermediate equipment that connects two or more subnetworks using a network layer relay function

3.1.2.18
RTE station
station with real-time capability

3.1.2.19
segment
communication channel that connects two nodes directly without intervening bridges

3.1.2.20
station
end node or a pair of end nodes that perform a specific application function

3.1.2.21
station number
numeric identifier which indicates a RTE station

3.1.2.22
subnetwork
part of a network that does not contain any routers. A subnetwork consists of end nodes, bridges and segments

NOTE Every end node included in a subnetwork has the same IP network address.

3.2 Abbreviations and symbols

3.2.1 ISO/IEC 10731 abbreviations

OSI	Open Systems Interconnection

3.2.2 Other abbreviations and symbols

ASS	acknowledged sequence of unitdata transfer service
AUS	acknowledged unitdata transfer service
DL-	Data-link layer (as a prefix)
DLE	DL-entity (the local active instance of the data-link layer)
DLL	DL-layer
DLM	DL-management
DLMS	DL-management Service
DLPDU	DL-protocol-data-unit
DLS	DL-service
DLSAP	DL-service-access-point
DLSDU	DL-service-data-unit
FIFO	first-in first-out (queuing method)
ID	identifier
IEC	International Electrotechnical Commission
ind	indication primitive
IP	Internet protocol
ISO	International Organization for Standardization
LLC	logical link control
lsb	least significant bit
MAC	medium access control
msb	most significant bit
MSS	multipoint sequence of unitdata transfer service
MUS	multipoint unitdata transfer service
PDU	protocol data unit
Ph-	physical layer (as a prefix)
PhL	Ph-layer
QoS	quality of service
req	request primitive
rsp	response primitive
SAP	service access point
SDU	service data unit
ToS	type of device
UUS	unacknowledged unitdata transfer service

3.3 Conventions

3.3.1 General conventions

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

3.3.2 Conventions for DLE protocol procedure definitions

The conventions used for DLE state machine definitions are described in Table 1.

Table 1 – Conventions used for protocol procedure definitions

Event	Condition	Procedure
Events that trigger these actions	Conditions	Actions that are taken when the events and conditions are met

4 Overview of the DL-protocol

4.1 General

The Data Link Layer provides basic real-time and reliable communications between devices in automation environments.

This part of the document specifies

a) procedures of the Data Link (DL) protocols for real-time data transfer and control information from one Data Link Service 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 Data Link Protocol Data Units (DLPDUs) used for data transfer and control information, and their mapping to the underlying layers.

The procedures are defined in terms of

a) the interactions between peer DL-entities (DLEs) through the exchange of fieldbus Data Link Protocol Data Units;
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 Physical Service provider in the same system through the exchange of Ph-service primitives.

4.2 Characteristics of the protocol

The requirements of continuous process control, e.g. in the Oil and Gas, Petrochemical and Chemical, Pharmaceutical and Power industries, result in the following characteristic features of the Data Link protocol.

The maximum system size for this protocol is 254 subnetworks of 254 nodes, where each node has 254 DLSAP-addresses. All Data Link entities can communicate with all others in a cyclic or acyclic manner with prioritized access, or in a combination of the two.

This protocol provides real-time communication by means of transmission scheduling. The minimum cycle-time of scheduling is 10 ms. In addition, it provides a means to maintain clock synchronization across a subnetwork with a precision better than 1 ms, and across an extended network with a precision better than 5 ms.

This protocol provides reliable and flexible communications by remotely confirmed acyclic data transfer with retransmission. In addition, it provides a dual-redundant network with a switchover time of less than 100 ms, and also provides the facilities for dual-redundant devices.

4.3 Data-link layer architecture

4.3.1 General

The DLL is modeled as

a) a real-time data transfer function;

b) a datagram transfer function;

c) a network routing function;

d) a media access function;

e) a logical link and management function.

With the exception of the real-time data transfer function, each function is implemented according to the following existing protocols specified in Table 2.

Table 2 – Referenced standards for the layers

Function	Compliance
Datagram transfer function	RFC 768 (UDP)
Network routing function	RFC 791 (IP)
Media access function	ISO/IEC 8802-3, IEEE Std 802.3ab

4.3.2 Real-time data transfer function

The real-time data transfer function is specified in this specification, and it provides the Connectionless-mode Data Link Service specified in IEC 61158-3-17.

4.3.3 Datagram transfer function

The datagram transfer function is compliant with RFC 768 (UDP definition) and provides datagram transfer service for the real-time data transfer function.

4.3.4 Network routing function

The network routing function is compliant with RFC 791 (IP definition) and provides datagram routing service for the datagram transfer function.

This function also performs fragmentation of a datagram to maintain independence from MTU of the underlying sublayer. The function utilizes two logical link functions to realize a dual-redundant network.

In a dual-redundant station, two network routing entities are implemented for both end nodes.

4.3.5 Logical link and media access function

The logical link and media access function is compliant with ISO/IEC 8802-3. It provides fragments transfer service within a subnetwork and a means of accessing the network for the network routing function.

Two entities that execute media access function are implemented in a node to realize a dual-redundant network.

4.3.6 Management function

The management function is specified in this specification, and it provides the DL-management Service and DLSAP management Data Link Service. These services are specified in IEC 61158-3-17.

4.4 Services provided by the DLL

4.4.1 General

The services provided by the DLL are specified in IEC 61158-3-17.

There are three types of Data Link Service:

a) a Connectionless-mode Data Link Service;
b) a DLSAP management Data Link Service;
c) a DL-management Service.

4.4.2 Quality of Service (QoS) attributes

QoS attributes specified by the DLS-user select some aspects of the various Data Link Services, and can be specified only when a DLSAP-address is bound to the DLS-user's DLSAP.

4.4.2.1 Service subtype

This attribute determines a service subtype of data transfer service of DLSAP specified by DL-BIND request.

Each service subtype has different data delivery features and different data transfer relationships i.e., the point-to-point or multipoint model. Some QoS attributes are limited by the type of service subtype.

There are five service subtypes.

a) Unacknowledged Unitdata transfer Service (UUS).
b) Acknowledged Unitdata transfer Service (AUS).
c) Acknowledged Sequence of unitdata transfer Service (ASS).
d) Multipoint Unitdata transfer Service (MUS).
e) Multipoint Sequence of unitdata transfer Service (MSS).

4.4.2.2 DLL maximum confirm delay

This attribute determines the upper bound on the time delay permitted until the DL-UNITDATA service is confirmed, i.e., the maximum permissible delay between the issuing of a DL-UNITDATA request primitive and receiving of the corresponding DL-UNITDATA confirm primitive.

The parameter specifies an interval from 1 ms to 60 s inclusive in units of 1 ms.

4.4.2.3 DLL priority

This attribute specifies an associated DLL priority used in scheduling DLL data transfer services. The DL-protocol should support four DLL priority levels. The four DLL priorities, from highest to lowest priority, are as follows.

a) URGENT
b) HIGH
c) NORMAL
d) TIME-AVAILABLE

The priority attribute assigned for each DLSDU is recognized by both of the sending DLE and receiving DLE, and it may be translated to the underlying service QoS parameter which is used by lower entities to control the priority of PDU transfer.

In the sending DLE, DLSDU with higher priority requested by a DL-UNITDATA request primitive is transmitted in advance of any other DLSDUs with lower priority.

In the receiving DLE, the received DLPUD with higher priority is delivered to the DLS-user in advance of any other DLPDUs with lower priority.

4.4.2.4 Maximum DLSDU size

The DLS-user data requested by DL-UNITDATA request are conveyed in a single DLPDU. The Maximum DLSDU size attribute specifies an upper bound on the size (in octets) of DLSDUs that will be offered for transmission, and an upper bound on the size of DLSDUs that are acceptable for reception.

The parameter shall be chosen from 256 × N, where 1 ≤ N ≤ 16.

NOTE The maximum size of DLSDU supported for DLSAP, which is assigned as Acknowledged Unitdata transfer Service (AUS) for service subtype, is limited to 2 048.

4.4.2.5 Authentication level

This attribute specifies the level of authentication for data transfer. The following four alternative levels are available:

a) “no authentication”;
b) “use 64-bit key code”;
c) “use 128-bit key code”;
d) “use 256-bit key code”.

4.4.2.6 Maximum residual error rate

This parameter specifies upper bound on acceptable residual error rate of the underlying layer service.

The DLL monitors the bit error rate of the underlying layer service continuously. Under conditions where the residual error rate, calculated from the bit error rate and the error detection performance, is higher than the maximum residual error rate, the requested DL-UNITDATA request is completed with error.

This feature supports the DLS-user switching the sending interface to prevent unexpected loss of data integrity caused by the underlying service.

4.5 Network sharing with other protocols

Other TCP-based protocols, such as HTTP and FTP, can work on the same network alongside communication of the DLE. In this case, total traffic of communication based on other protocols shall be limited by some means such as switching hubs. The methods for limitation are outside the scope of this standard.

5 DLPDU-parameter structure and encoding

5.1 Overview

The specification of the transfer syntax combines the specification of the abstract syntax and their encodings as a set of fixed-format DLPDUs. Each DLPDU contains a DLPDU common header and a DLPDU body.

The DLPDU body consists of an individual header, which is specified by the service subtype, and the DLSDU.

5.1.1 Data type encodings

The following data types, which are specified in Part 3 of this document, are used in DLPDU definitions.

a) Unsigned8
b) Unsigned16
c) Unsigned32
d) OctetString.

The bit positions in an octet value are defined in Table 3.

Table 3 – Bit positions

Bit position	Hex value	Decimal value
8	0x80	128
7	0x40	64
6	0x20	32
5	0x10	16
4	0x08	8
3	0x04	4
2	0x02	2
1	0x01	1

5.1.2 Structure and definition of DL-addresses

Although the DLS conforms formally to the “three-layer” Fieldbus Reference Model, it actually utilizes the Network Layer Service of the OSI Basic Reference Model and IP address specified by RFC 791.

The IP unicast and multicast addresses shall be used as the DL-address.

5.2 DLPDU common header format

Table 4 defines the common header format.

Table 4 – Common header format

Parameter name	Octet offset	Data type	Octet length	Description
DLPUD Version	0	Unsigned8	1	Specifies the Version number of the DLPDU format. The version number of the DLPDUs specified in this edition is 1 1 = Version 1
PDU type	1	Unsigned8	1	Indicates DLPDU attribute Bit 8: 1= Multicast Bit 7: 1= For external of the domain Bit 6: 1= Response Bit 5: 1= Remote confirmation is requested Bits 4-3: Indicates destination SAP-ID 0= DLS-user (SAP) 1= DL Management 2= Reserved 3= Reserved Bits 2-1: Indicates destination extension 0= Don't care 1= On-service end node 2= Standby end node 3= Both
Service Subtype	2	Unsigned8	1	Indicates the subtype of service Bits 8-5: 1= UUS 2= AUS 3= ASS 4= MUS 5= MSS All other values are reserved Bits 4-1: reserved
Option	3	Unsigned8	1	Indicates the options Bits 8-5: indicates security option 0= No security control 1= 2 octet authentication data, simplified control 2= 2 octet authentication data, full control 3= 4 octet authentication data, simplified control 4= 4 octet authentication data, full control All other values are reserved Bits 4-1: indicate safety option 0= No safety control All other values are reserved
Total Length	4	Unsigned32	4	Indicates octet length of the DLPDU
Authentication Data	8	Unsigned	n	Authentication data created according to the security type The length is specified by the security option
Integrity Data	8+n	Unsigned	m	Authentication data created according to the security type The length is specified by the safety option

5.3 DLPDU body format

There are 8 kinds of DLPDU. Table 5 is the list of DLPDUs.

Table 5 – DLPDU types

DLPDU name	Description
UUS_DT_PDU	This PDU conveys DLSDU of UUS service
AUS_DT_PDU	This PDU conveys DLSDU of AUS service
AUS_RSP_PDU	This PDU is used to respond to the AUS_DATA_PDU
ASS_DT_PDU	This PDU conveys DLSDU of AAS service
ASS_ENQ_PDU	This PDU is used to enquire whether ASS_DTPDUs are received
ASS_RSP_PDU	This PDU is used to respond to the ASS_ENQ_PDU
MUS_DT_PDU	This PDU conveys DLSDU of MUS service
MSS_DT_PDU	This PDU conveys DLSDU of MSS service

Table 6 defines assignment of the Service Subtype and PDU type field of the common header for each DLPDU.

Table 6 – Service subtype and PDU type of DLPDUs

DLPDU type	Service subtype	PDU type					
		Multicast	External	Response	Confirm	SAP-ID	Extension
UUS_DATA	1	0	0/1	0	0	DEPND	DEPND
AUS_DATA	2	0	0	0	1	DEPND	DEPND
AUS_RSP	2	0	0	1	0	DEPND	DEPND
ASS_DATA	3	0	0/1	0	0	DEPND	DEPND
ASS_ENQ	3	0	0/1	0	1	DEPND	DEPND
ASS_RSP	3	0	0/1	1	0	DEPND	DEPND
MUS_DATA	4	1	0/1	0	0	DEPND	DEPND
MSS_DATA	5	1	1/1	0	0	DEPND	DEPND

5.3.1 Common parameter of DLPDU body

The common parameters are defined as follows.

Service subtype
This parameter is the same as Service Subtype in the common header.

PDU subtype
This parameter specifies the subtype that represents the role of the DLPDU.

Status
This parameter indicates the status of the transaction.

Sequence number
This parameter identifies the DT_PDU, and is also used to inform the latest received DT_PDU in the RSP_PDUs.

DLSAP ID

This parameter indicates the DLSAP identifier.

DLSDU length
This parameter indicates the octet length of the DLSDU.

DLSDU
This parameter is the user data requested by the Unitdata request.

5.3.2 DLPDU format for UUS

Table 7 indicates the body format of DLPDU for UUS.

Table 7 – UUS_DT_PDU

Parameter name	Octet offset	Data type	Octet length	Description
Service subtype	0	Unsigned8	1	Same as service subtype in common header Bits 8-5: 1 (UUS) Bits 4-1: reserved
PDU Subtype	1	Unsigned8	1	Indicates the subtype of DLPDU Bits 8-5: 1 = DATA Bits 4-1: reserved
Status	2	Unsigned8	1	Not Used, set to 0
Sequence number	3	Unsigned8	1	Identifies PDU in the sequence of PDUs
DLSAP ID	4	Unsigned16	2	Indicates DLSAP identifier
DLSDU Length	6	Unsigned16	2	Indicates octet length of the DLSDU
DLSDU	8	OctetString	-	DLSDU requested by DLS-user The length of DLSDU is specified by the DLSDU length

5.3.3 DLPDU format for AUS

Table 8 and Table 9 indicate body formats of DLPDU for AUS.

Table 8 – AUS_DT_PDU

Parameter name	Octet offset	Data type	Octet length	Description
Service subtype	0	Unsigned8	1	Same as service subtype in common header Bits 8-5: 2 (AUS) Bits 4-1: reserved
Subtype	1	Unsigned8	1	Indicates the subtype of DLPDU Bits 8-5: 1 = DATA Bits 4-1: reserved
Status	2	Unsigned8	1	Indicates status of the transaction Bits 8-5: reserved Bits 4-1: Retry count
Sequence number	3	Unsigned8	1	Identifies PDU in the sequence of PDUs
DLSAP ID	4	Unsigned16	2	Indicates DLSAP identifier
DLSDU Length	6	Unsigned16	2	Indicates octet length of the DLSDU
DLSDU	8	OctetString	-	DLSDU requested by DLS-user The length of DLSDU is specified by the DLSDU length

Table 9 – AUS_RSP_PDU

Parameter name	Octet offset	Data type	Octet length	Description
Service subtype	0	Unsigned8	1	Same as service subtype in common header Bits 8-5: 2 (AUS) Bits 4-1: reserved
Subtype	1	Unsigned8	1	Indicates the subtype of DLPDU Bits 8-5: 8 = RESPONE Bits 4-1: reserved
Status	2	Unsigned8	1	Indicates the status of response 0= Normal 1= reserved 2= Buffer busy 3= Sequence error
Sequence number	3	Unsigned8	1	Identifies Sequence number expected for next DT_PDU
DLSAP ID	4	Unsigned16	2	Indicates DLSAP identifier
DLSDU Length	6	Unsigned16	2	Always set to 0

5.3.4 DLPDU format for ASS

Table 10, Table 11 and Table 12 indicate body formats of DLPDU for ASS.

Table 10 – ASS_DT_PDU

Parameter name	Octet offset	Data type	Octet length	Description
Service subtype	0	Unsigned8	1	Same as service subtype in common header Bits 8-5: 3 (ASS) Bits 4-1: reserved
Subtype	1	Unsigned8	1	Indicates the subtype of DLPDU Bits 8-5: 1 = DATA Bits 4-1: reserved
Status	2	Unsigned8	1	Indicates status of the transaction Bit 8: 1= Initial PDU of sequence Bits 4-1: Retry count All other bits are reserved
Sequence number	3	Unsigned8	1	Identifies PDU in the sequence of PDUs It is managed for each remote IP address
DLSAP ID	4	Unsigned16	2	Indicates DLSAP identifier
DLSDU Length	6	Unsigned16	2	Indicates octet length of the DLSDU
DLSDU	8	OctetString	-	DLSDU requested by DLS-user The length of DLSDU is specified by the DLSDU length

Table 11 – ASS_ENQ_PDU

Parameter name	Octet offset	Data type	Octet length	Description
Service subtype	0	Unsigned8	1	Same as service subtype in common header Bits 8-5: 3 (ASS) Bits 4-1: reserved
Subtype	1	Unsigned8	1	Indicates the subtype of DLPDU Bits 8-5: 4 = ENQ Bits 4-1: reserved
Status	2	Unsigned8	1	Indicates status of the transaction Bits 4-1: Retry count All other bits are reserved
Sequence number	3	Unsigned8	1	Identifies the expected sequence number in the response PDUs
DLSAP ID	4	Unsigned16	2	Indicates DLSAP identifier
DLSDU Length	6	Unsigned16	2	Always set to 0

Table 12 – ASS_RSP_PDU

Parameter name	Octet offset	Data type	Octet length	Description
Service subtype	0	Unsigned8	1	Same as service subtype in common header Bits 8-5: 3 (ASS) Bits 4-1: reserved
Subtype	1	Unsigned8	1	Indicates the subtype of DLPDU Bits 8-5: 8 = RESPONSE Bits 4-1: reserved
Status	2	Unsigned8	1	Indicates the status of response 0= Normal 1= reserved 2= Buffer busy 3= Sequence error
Sequence number	3	Unsigned8	1	Identifies Sequence number expected for next DT_PDU
DLSAP ID	4	Unsigned16	2	Indicates DLSAP identifier
DLSDU Length	6	Unsigned16	2	Always set to 0

5.3.5 DLPDU format for MUS

Table 13 indicates the body format of DLPDU for MUS.

Table 13 – MUS_DT_PDU

Parameter name	Octet offset	Data type	Octet length	Description
Service subtype	0	Unsigned8	1	Same as service subtype in common header Bits 8-5: 4 (MUS) Bits 4-1: reserved
Subtype	1	Unsigned8	1	Indicates the subtype of DLPDU Bits 8-5: 1 = DATA Bits 4-1: reserved
Status	2	Unsigned8	1	Indicates DLSAP identifier
Sequence number	3	Unsigned8	1	Identifies PDU in the sequence of PDUs
DLSAP ID	4	Unsigned16	2	Not Used, set to 0
DLSDU Length	6	Unsigned16	2	Indicates octet length of the DLSDU
DLSDU	8	OctetString	-	DLSDU requested by DLS-user The length of DLSDU is specified by the DLSDU length

5.3.6 DLPDU format for MSS

Table 14 indicates the body format of DLPDU for MSS.

Table 14 – MSS_DT_PDU

Parameter name	Octet offset	Data type	Octet length	Description
Service subtype	0	Unsigned8	1	Same as service subtype in common header Bits 8-5: 5 (MSS) Bits 4-1: reserved
Subtype	1	Unsigned8	1	Indicates the subtype of DLPDU Bits 8-5: 1 = DATA Bits 4-1: reserved
Status	2	Unsigned8	1	Not Used, set to 0
Sequence number	3	Unsigned8	1	Identifies PDU in the sequence of PDUs
DLSAP ID	4	Unsigned16	2	Indicates DLSAP identifier
DLSDU Length	6	Unsigned16	2	Indicates octet length of the DLSDU
DLSDU	8	OctetString	-	DLSDU requested by DLS-user The length of DLSDU is specified by the DLSDU length

6 Local parameters and resources

6.1 General

The Data Link Layer uses the following local parameters and resources:

- system parameters P(…);
- local variables V(…);
- local timers T(…);
- local counters C(…).

Unless otherwise specified, at the moment of creation of these resources 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.

DL-management may change the values of configuration variables.

The following data types, which are specified in IEC 61158-6-17, are used in the definitions of parameters and resources.

- Boolean
- Integer
- BinaryTime2 (1 ms resolution)
- BinaryTime5 (1 s resolution)
- IPaddress.

6.2 Parameters and resources related to network structure

Table 15 lists the parameters and resources related to the network structure.

Table 15 – Parameters and resources for the network structure

Symbol	Name	Description
P(ND)	max-domains	Maximum number of domains
P(HC)	max-hop-count	Maximum hop-count of the network
P(NS)	max-stations	Maximum number of stations in a domain
$P(GA_{1A})$	IP-group-address-1A	IP-group-address of the multicast to all nodes in the domain for interface A
$P(GA_{1B})$	IP-group-address-1B	IP-group-address of the multicast to all nodes in the domain for interface B
$P(GA_{2A})$	IP-group-address-2A	IP-group-address of the multicast to all nodes of the network for interface A
$P(GA_{2B})$	IP-group-address-2B	IP-group-address of the multicast to all nodes of the network for interface B
$P(AB_{DA})$	IP-base-address-domain-A	Base subnet-address of domains for interface A
$P(AB_{DB})$	IP-base-address-domain-B	Base subnet-address of domains for interface B
V(TD)	this-domain	Domain number of this domain The possible range of values is 1 to P(ND)
V(TS)	this-station	Station number of this station The possible range of values is 1 to P(NS)
V(RID)	redundant-node-ID	End node Identifier of the redundant station Possible values are “0” and “1”
$V(IP_A)$	IP-address-A	IP-address for interface A This variable is assigned according to the P(TD), $P(AB_{DA})$, P(TS) and P(RID) $V(IP_A) = P(AB_{DA}) + P(TD) + P(TS) \text{ x2} + P(RID)$
$V(IP_B)$	IP-address-B	IP-address for interface B This variable is assigned according to the P(TD), $P(AB_{DB})$, P(TS) and P(RID) $V(IP_B) = P(AB_{DB}) + P(TD) + P(TS) \text{ x2} + P(RID)$

Table 16 defines the permissible ranges of the parameters.

Table 16 – Ranges of parameters for the network structure

Parameter	Data type	Range
P(ND)	Integer	1 to 254
P(HC)	Integer	1 to 16
P(NS)	Integer	1 to 254
P(GA_{1A})	IPaddress	any IPv4 group address
P(GA_{1B})	IPaddress	any IPv4 group address
P(GA_{2A})	IPaddress	any IPv4 group address
P(GA_{2B})	IPaddress	any IPv4 group address
P(AB_{DA})	IPaddress	any IPv4 Class C unicast address
P(AB_{DB})	IPaddress	any IPv4 Class C unicast address

6.3 Parameters and resources to support real-time data transfer

Table 17 lists the parameters and resources used to support real-time data transfer.

Table 17 – Parameters and resources real-time data transfer

Symbol	Name	Description
P(MRC_{AUS})	max-retry-count-AUS	Maximum retry count for AU
P(MRC_{ASS})	max-retry-count-ASS	Maximum retry count for ASS
P(MOS)	max-outstanding-number	Maximum outstanding number of PDUs for ASS before the ENQ_PDU
P(TNR_{AUS})	max-response-time-AUS	Expiration time of no-response-timer for AUS
P(TNR_{ASS})	max-response-time-ASS	Expiration time of no-response-timer for ASS
P(TWT_{AUS})	wait-time-AUS	Wait time between receiving of RSP_PDU with buffer busy status and successive retransmission of DT_PDU for AUS
P(TWT_{ASS})	wait-time-ASS	Wait time between receiving of RSP_PDU with buffer busy status and successive retransmission of ENQ_PDU for ASS
P(TID_{ASS})	inter-DTPDU-time	Interval time value between last ASS_DT_PDU and ENQ_PDU
C(RT_{AUS})	transfer-retry counter	This counter counts the number of retries
C(RT_{ASS})	transfer-retry counter	This counter counts the number of retries
C(OS)	outstanding-counter	This counter counts the number of ASS_DT_PDU before ENQ_PDU
T(NR_{AUS})	no-response-timer	This timer is used to monitor the RSP_PDU
T(NR_{ASS})	no-response-timer	This timer is used to monitor the RSP_PDU
T(ID_{ASS})	inter-DTPDU-timer	This timer is used to monitor the interval between two successive ASS_DT_PDUs
V(SQ_{SND})	PDU-sequence-number-sending	This variable is local to the sequence number that is used for the next DT_PDU
V(SQ_{RCV})	PDU-sequence-number-received	This variable is local to the sequence number of the latest DT_PDU received

Table 18 defines the permissible ranges of the parameters.

Table 18 – Ranges of parameters for real-time data transfer

Parameter	Data type	Range
P(MRC_{AUS})	Integer	0 or an odd number out from 1 to 15
P(MRC_{ASS})	Integer	0 or an odd number out from 1 to 15
P(MOS)	Integer	1 to 255
P(TNR_{AUS})	BinaryTime2	1 to 255 ms
P(TNR_{ASS})	BinaryTime2	1 to 255 ms
P(TWT_{AUS})	BinaryTime2	1 to 255 ms
P(TWT_{ASS})	BinaryTime2	1 to 255 ms
P(TID_{ASS})	BinaryTime2	10 to 2 047 ms

6.4 Parameters and resources to support the scheduling function

Table 19 lists the parameters and resources used to support the scheduling function.

Table 19 – Parameters and resources for scheduling function

Symbol	Name	Description
P(MC)	macro-cycle-period	Time period of a macro cycle
$P(SD_{UUS})$	starting-delay-UUS	List of starting delay time of UUS slots
$P(SD_{AUS})$	starting-delay-AUS	List of starting delay time of AUS slots
$P(SD_{ASS})$	starting-delay-ASS	List of starting delay time of ASS slots
$P(SD_{MUS})$	starting-delay-MUS	List of starting delay time of MUS slots
$P(SD_{MSS})$	starting-delay-MSS	List of starting delay time of MSS slots
$P(TD_{UUS})$	time-duration-UUS	Time duration UUS slot
$P(TD_{AUS})$	time-duration-AUS	Time duration AUS slot
$P(TD_{ASS})$	time-duration-ASS	Time duration ASS slot
$P(TD_{MUS})$	time-duration-MUS	Time duration MUS slot
$P(TD_{MSS})$	time-duration-MSS	Time duration MSS slot
$P(TO_{UUS})$	offset-time-UUS	Offset time of UUS slot
$P(TO_{AUS})$	offset-time-AUS	Offset time of AUS slot
$P(TO_{ASS})$	offset-time-ASS	Offset time of ASS slot
$P(TO_{MUS})$	offset-time-MUS	Offset time of MUS slot
$P(TO_{MSS})$	offset-time-MSS	Offset time of MSS slot
$P(DV_{UUS})$	divisor-for-grouping	Divisor value of modulo for the offset grouping of UUS
$P(DV_{AUS})$	divisor-for-grouping	Divisor value of modulo for the offset grouping of AUS
$P(DV_{ASS})$	divisor-for-grouping	Divisor value of modulo for the offset grouping of ASS
$P(DV_{MUS})$	divisor-for-grouping	Divisor value of modulo for the offset grouping of MUS
$P(DV_{MSS})$	divisor-for-grouping	Divisor value of modulo for the offset grouping of MSS
T(SCH)	scheduling-timer	This timer is used to recognize each slot.

Table 20 defines the permissible ranges of the parameters.

Table 20 – Ranges of parameters for scheduling

Parameter	Data type	Range
P(MC)	BinaryTime2	10 ms to 1 000ms
P(SD_{UUS})	Array of BinaryTime2	Each value is in the range from 0 ms to P(MC)
P(SD_{AUS})	Array of BinaryTime2	Each value is in the range from 0 ms to P(MC)
P(SD_{ASS})	Array of BinaryTime2	Each value is in the range from 0 ms to P(MC)
P(SD_{MUS})	Array of BinaryTime2	Each value is in the range from 0 ms to P(MC)
P(SD_{MSS})	Array of BinaryTime2	Each value is in the range from 0 ms to P(MC)
P(TD_{UUS})	BinaryTime2	1 ms to (P(MC) – 1 ms)
P(TD_{AUS})	BinaryTime2	1 ms to (P(MC) – 1 ms)
P(TD_{ASS})	BinaryTime2	1 ms to (P(MC) – 1 ms)
P(TD_{MUS})	BinaryTime2	1 ms to (P(MC) – 1 ms)
P(TD_{MSS})	BinaryTime2	1 ms to (P(MC) – 1 ms)
P(TO_{UUS})	BinaryTime2	0 ms to P(TD_{UUS})
P(TO_{AUS})	BinaryTime2	0 ms to P(TD_{AUS})
P(TO_{ASS})	BinaryTime2	0 ms to P(TD_{ASS})
P(TO_{MUS})	BinaryTime2	0 ms to P(TD_{MUS})
P(TO_{MSS})	BinaryTime2	0 ms to P(TD_{MSS})
P(DV_{UUS})	Integer	1 to 255
P(DV_{AUS})	Integer	1 to 255
P(DV_{ASS})	Integer	1 to 255
P(DV_{MUS})	Integer	1 to 255
P(DV_{MSS})	Integer	1 to 255

6.5 Parameters and resources to support the security function

Table 21 lists the parameters and resources used to support the security function.

Table 21 – Parameters and resources for security function

Symbol	Name	Description
P(KS)	key size	Size of the keys in octet
P(AS)	authentication field size	Size of the authentication field in octet
P(PN)	prime-number	Prime number for the key generation
P(BS)	base-number	Base number for the key generation
P(UD)	key-update-time	Time period over which the key is updated
T(UD)	key-update-timer	This timer generates update timing of the key

Table 22 lists the permissible ranges of the parameters.

Table 22 – Ranges of parameters for security function

Parameter	Data type	Range
P(KS)	Integer	1,2,4,8,16
P(AS)	Integer	1,2,4,8,16,32,64
P(PN)	Integer	0 to P(KS)
P(BS)	Integer	0 to P(PN)
P(UD)	BinaryTime5	1 to 3 600 s

7 DL-service elements of procedure

7.1 Unacknowledged unitdata transfer service (UUS)

The procedure of UUS is described in Table 23.

Table 23 – UUS procedure

Event	Condition	Procedure
DL-UNITDATA request		1) Selects a transmit interface and a destination IP address, according to the network status table 2) Transmits UUS_DT_PDU with $V(SQ_{SND})$ 3) Issues a DL- UNITDATA confirm
Receiving DT_PDU	seqNo <> $V(SQ_{RCV})$	1) Issues a DL-UNITDATA indication primitive at the DLSAP with DLSDU 2) Updates $V(SQ_{RCV})$
	seqNo = $V(SQ_{RCV})$	1) No action taken

7.2 Acknowledged unitdata transfer service (AUS)

The procedure of AUS is described in Table 24.

Table 24 – AUS procedure

Event	Condition	Procedure
DL-UNITDATA request		1) Transmits AUS_DT_PDU for the destination 2) Starts T(NR)
Receive RSP_PDU	Expected RSP_PDU && status = "normal"	1) Issues a DL- UNITDATA confirm with DLSDU
	Expected RSP_PDU && status = "buffer busy" && $C(RT_{AUS}) < P(MRC_{AUS})$	1) wait $P(TWT_{AUS})$ 2) Retransmits DT_PDU 3) Increments $C(RT_{AUS})$
	Expected RSP_PDU && status = "buffer busy" && $C(RT_{AUS}) = P(MRC_{AUS})$	1) Issues a DL-UNITDATA confirm with error status
$T(NR_{AUS}) = P(TNR_{AUS})$	$C(RT_{AUS}) < P(MRC_{AUS})$	1) Updates network status table accordingly 2) Selects a transmit interface and a destination IP address, accordingly 3) Retransmits AUS_DT_PDU
	$C(RT_{AUS}) = P(MRC_{AUS})$	1) Issues a DL- UNITDATA confirm with error status
Receive DT_PDU	seqNo <> $V(SQ_{RCV})$ && buffer is available	1) Issues a DL-UNITDATA indication primitive at the DLSAP with DLSDU 2) Updates $V(SQ_{RCV})$ 3) Transmits RSP_PDU
	seqNo <> $V(SQ_{RCV})$ && buffer is not available	1) Transmits RSP_PDU with "buffer busy" status
	seqNo = $V(SQ_{RCV})$	1) Transmits RSP_PDU

7.3 Acknowledged sequence of unitdata transfer service (ASS)

The procedure of ASS is described in Table 25.

Table 25 – ASS procedure

Event	Condition	Procedure
DL-UNITDATA request	wait_flag = "false"	1) Transmits DT_PDU with V(SQ_{SND}) 2) Issues a DL- UNITDATA confirm normally 3) Increments C(OS) 4) Starts T(ID)
	wait_flag = "true"	1) Waits until wait flag becomes false
C(OS) = P(MOS)		1) Transmits ENQ_PDU 2) Sets wait_flag 3) Starts T(NR_{ASS})
T(ID_{ASS}) =P(TID_{ASS})		1) Transmits ENQ_PDU 2) Sets wait_flag 3) Starts T(NR_{ASS})
T(NR_{ASS}) = P(TNR_{ASS})	C(RT_{ASS}) < P(MRC_{ASS})	1) Retransmits ENQ_PDU 2) Increments C(RT_{ASS}) 3) Starts T(NR_{ASS})
	C(RT_{ASS}) = P(MRC_{ASS})	1) Clears wait flag 2) Clears V(SQ_{SND})
Receive RSP_PDU	seqNo = V(SQ_{SND})	1) Clears wait_flag
	seqNo <> V(SQ_{SND}) && C(RT_{ASS}) < P(MRC_{ASS})	1) Retransmit DT_PDUs from DT_PDU with seqNo in the RSP_PDU 2) Transmits ENQ_PDU 3) Increments C(RT_{ASS}) 4) Starts T(NR_{ASS})
	seqNo <> V(SQ_{SND}) && C(RT_{ASS}) = P(MRC_{ASS})	1) Clears wait_flag 2) Clears V(SQ_{SND})
	status = "buffer busy" && C(RT_{ASS}) < P(MRC_{ASS})	1) Retransmit DT_PDUs from DT_PDU with seqNo in the RSP_PDU 2) Waits P(TWT_{ASS}) 3) Transmits ENQ_PDU 4) Increments C(RT_{ASS}) 5) Starts T(NR_{ASS})
	status = "buffer busy" && C(RT_{ASS}) < P(MRC_{ASS})	1) Clears wait flag 2) Clears V(SQ_{SND})
Receive DT_PDU	seqNo = "0" && buffer is available	1) Issues a DL-UNITDATA indication primitive at the DLSAP with DLSDU 2) Clears busy_flag 3) Update V(SQ_{RCV})
	seqNo = V(SQ_{RCV}) + 1 && buffer is available	1) Issues a DL-UNITDATA indication primitive at the DLSAP with DLSDU 2) Update V(SQ_{RCV})
	seqNo = V(SQ_{RCV}) + 1 && buffer is not available	1) Discard the DT_PDU 2) Sets busy_flag
	seqNo <> V(SQ_{RCV}) + 1	1) no action taken
Receive EQ_PDU	busy_flag = "false"	1) Transmits RSP_PUD with V(SQ_{RCV})
	busy_flag = "true"	1) Transmits RSP_PUD with V(SQ_{RCV}) and "buffer busy" status

7.4 Multipoint unitdata transfer service (MUS)

The procedure of MUS is described in Table 26.

Table 26 – MUS procedure

Event	Condition	Procedure
DL-UNITDATA request		1) Sends DT_PDU 2) Issues a DL- UNITDATA confirm
Receive DT_DLPDU		1) Issues a DL-UNITDATA indication primitive at the DLSAP with DLSDU

7.5 Multipoint sequence of unitdata transfer service (MSS)

The procedure of MSS is described in Table 27.

Table 27 – MSS procedure

Event	Condition	Procedure
Receipt of a DL-UNITDATA request primitive		1) Sends MSS_DT_PDU on both interfaces 2) Initiates a DL- UNITDATA confirm
Receipt of a ENQ_PUD	Requested DT-PDU is available	1) Sends MSS_DT_PDUs requested on both interfaces again
Receipt of a DT DLPDU	seqNo = $V(SQ_{RCV}) + 1$	1) Issues a DL-UNITDATA indication primitive at the DLSAP with DLSDU 2) Updates $V(SQ_{RCV})$
	seqNo <> $V(SQ_{RCV}) + 1$	1) Issues a DL-UNITDATA indication primitive at the DLSAP with DLSDU and sequence error status 2) Updates $V(SQ_{RCV})$

8 DL-support protocol

8.1 Transmission scheduling

8.1.1 Overview

The transmission timing of each DLPDU is scheduled in one or more time slot(s) within the macro-cycle. These time slots are specified by the system parameters according to the service subtype and the transmitting station number.

8.1.2 Macro-cycle

The macro-cycle is a base time period in which transmission is controlled. The duration of the macro-cycle is specified by the parameter macro-cycle-period P(MC). Every node has synchronized macro-cycle by means of a time synchronization mechanism.

NOTE This synchronization mechanism is outside the scope of this standard.

8.1.3 Transmission time slot

The transmission time slot for each service subtype is specified by the following parameters:

$P(SD_{XXX})$ starting-delay

$P(TD_{XXX})$ time-duration

$P(TO_{XXX})$ offset-time

$P(DV_{XXX})$ divisor-for-grouping

V(TS) this-station.

NOTE Suffixes of each parameter (“$_{XXX}$”) indicate the corresponding service subtype.

The start timing of each slot in the macro-cycle is specified by the following equation:

$$P(SD_{XXX}) + (V(TS) \% P(DV_{XXX})) X P(TO_{XXX})$$

where “%” indicates the modulo operator.

The end timing of each slot in the macro-cycle is specified by the following equation:

$$P(SD_{XXX}) + (V(TS) \% P(DV_{XXX})) X P(TO_{XXX}) + P(TD_{XXX})$$

8.1.4 Transmission scheduling

DT_PDUs are transmitted in the time slot that is selected according to the service subtype of the DT_PDU, and the other DL_PDUs may be transmitted at any time.

NOTE As the scheduling is controlled over the UDP service, the actual timing of transmission to medium is affected by the delay caused by the underlying layer service. Therefore, some considerations are required for implementation.

8.2 Redundancy

8.2.1 Network redundancy

8.2.1.1 General

The network always has a dual-redundant structure. Both the primary and secondary channels are diagnosed periodically by the application entities. The information concerning the consistency of channels is shared among all end nodes of the network and maintained in the network status table, which is specified in IEC 61158-6-17.

The interface to which DLPDU is transmitted is selected according to the network status table.

Each channel is basically used according to the following rules:

a) when both channels are consistent
   – use the primary channel;
b) when one of channel is inconsistent
   – use the consistent channel;
c) when both channels are inconsistent
   – use the channel that is likely to be consistent between two endpoints.

8.2.1.2 Channel redundancy for UUS

The DLE selects a transmission channel for UUS_DLPDUs and receives them as follows.

a) The DLE transmits UUS_DT_PDUs to the channel selected according to the general rule specified in 8.2.1.1.
b) The DLE receives every UUS_PDU regardless of the receiving channel.

8.2.1.3 Channel redundancy for AUS

The DLE selects a transmission channel for AUS_DLPDUs and receives them as follows.

a) The DLE first transmits a DT_PDU to the channel selected according to the general rule specified in 8.2.1.1. If errors are detected, the DLL retransmits the DT_PDU to the same channel. After retransmissions the number of which is half the maximum retry count, the DLE changes the transmission channel to the alternate channel.
b) The DLE always transmits RSP_PDU to the channel from which the DT_PDU was received.
c) The DLE receives the AUS_DT_PDU the sequence number of which is not the same as the value of the last received AUS_DT_PDU from the sending end node, regardless of the receiving channel.
d) The DLE receives every AUS_RSP_PDU regardless receiving channel.

8.2.1.4 Channel redundancy for ASS

The DLE selects a transmission channel for ASS_DLPDUs and receives them as follows.

a) The DLE transmits a DT_PDU to the channel selected according to the general rule specified in 8.2.1.1.
b) The DLE transmits an ENQ_PDU to the channel selected according to the general rule specified in 8.2.1.1.

NOTE The application entity checks the consistency of the channels periodically and updates the network status table. Consequently, the channel for retransmission is changed to the alternate channel.

c) The DLE always transmits RSP_PDU to both of the redundant channels.

d) The DLE receives the ASS_DT_PDU the sequence number of which is not the same as the value of the last received ASS_DT_PDU from the sending end node, regardless of the receiving channel.

e) The DLE receives the ASS_ENQ_PDU regardless of the receiving channel.

f) The DLE receives the ASS_RSP_PDU regardless of the receiving channel.

8.2.1.5 Channel redundancy for MUS

The DLE selects the transmission channel for MUS_DLPDUs and receive them as follows.

a) The DLE always transmits DT_PDU for both of the redundant channels. Actually, it is realized by transmitting to two multicast addresses assigned for the primary and secondary networks.

b) The DLE receives the MUS_DT_PDU regardless of the receiving channel.

8.2.1.6 Channel redundancy for MSS

The DLE selects the transmission channel for MUS_DLPDUs and receive them as follows.

a) The DLE always transmits DT_PDU for both of the redundant channels. Actually, it is realized by transmitting to two multicast addresses assigned for the primary and secondary networks.

b) The DLE receives the MSS_DT_PDU the sequence number of which is not the same as the value of the last received MSS_DT_PDU from the sending end node, regardless of the receiving channel.

8.2.2 Station redundancy

8.2.2.1 General

A redundant station consists of two end nodes that have different DLSAPs. One end node is in the on-service state, and the other end node is in the standby state. Each end node acts according to its state. The switching over mechanism is outside the scope of this standard.

8.2.2.2 Actions of peer stations

The DLE of the station that communicates with a redundant station selects one end node of the redundant station as the destination according to the information in the network status table, as follows.

a) The DLE transmits UUS_DT_PDU to the end node in on-service state.

b) The DLE first transmits AUS_DT_PDU to the end node in the on-service state. If communication fails, it then transmits AUS_DT_PDU to the end node in the standby state.

c) The DLE transmits ASS_DT_PDU to both of the end nodes.

d) When the DLE user requests communication to the end node in the standby state, the destination end node is selected accordingly. In this case, the standby side shall be specified in the PDU type field of the DLPDU.

NOTE Consideration of destination end node is not needed for MUS and MSS communication because the destination address is a multicast address. This means that the DT_PDU is delivered to both end nodes of the redundant station.

8.2.2.3 Actions of on-service end node

The DLE of the end node in the on-service state acts as follows.

a) The DLE provides every DLE service to the DLS-user.

b) The DLE accepts every DT_PDU, and pass it to DLE-user by indication primitives.

c) The DLE accepts every ENQ_PDU and responds to it.

d) The DLE accepts every RSP_PDU responding to the ENQ_PDU sent.

8.2.2.4 Actions of standby end node

The DLE of the end node in the standby state acts as follows.

a) The DLE does not provide any DLE services to the DLS-user, except in the case where the “standby end node” is specified explicitly.
b) The DLE does not accept any DT_PDUs, except in the case where the “standby end node” is specified explicitly.
c) The DLE does not respond to any ENQ_PDUs, except in the case where the “standby end node” is specified explicitly.
d) The DLE does not accept any RSP_PDUs, except in the case where the “standby end node” is specified explicitly.

8.3 DLPDU authentication

Authentication of the DLPDUs may be applied for UUS_DT_PDUs, AUS_DT_PDUs and ASS_DT_PDUs. The authentication is realized by the authentication data field in the common header of the DLPDU.

The sending DLE puts authentication data into the DLPDU. The authentication data are generated from all octets of the DLPDU except the authentication data field, and the common secret key shared by both end nodes.

The receiving DLE checks the octets of the DLPDU including the authentication data field with the common secret key.

The method for authentication data generation and checking is outside the scope of this standard.

The common secret key is shared by means of the public key exchange method.

Both of the local end nodes generate a private number (x) for each. The method of the private key generation is outside the scope of this standard. In addition, the public key (y) is generated from the prime number (p) and the base number (g) assigned for the network as follows.

$$y = g^{x} \text{ modulo } p$$

All end nodes are informed of the public key by multicasting. This is realized by the application entity using the MUS DLE service.

The common secret key (z) is generated from the private number and the public key of the peer end node, as follows.

$$z = y^{x} \text{ modulo } p$$

The private number (x) shall be updated after every period specified by P(UD).

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