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Industrial communication networks – Fieldbus specifications –
Part 3-13: Data-link layer service definition – Type 13 elements

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INDUSTRIAL COMMUNICATION NETWORKS –
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Part 3-13: Data-link layer service definition – Type 13 elements

FOREWORD

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NOTE Use of some of the associated protocol types is restricted by their intellectual-property-right holders. In all cases, the commitment to limited release of intellectual-property-rights made by the holders of those rights permits a particular data-link layer protocol type to be used with physical layer and application layer protocols in type combinations as specified explicitly in the IEC 61784 series. Use of the various protocol types in other combinations may require permission of their respective intellectual-property-right holders.

International Standard IEC 61158-3-13 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 61158-3 subseries cancel and replace IEC 61158-3:2003. This edition of this part constitutes a technical addition. This part and its Type 13 companion parts also replace IEC/PAS 62408, published in 2005.

This edition includes the following significant technical changes with respect to 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 3-1, 3-2, …, 3-19.

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

FDIS	Report on voting
65C/473/FDIS	65C/484/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- withdrawn;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.

Throughout the set of fieldbus standards, the term “service” refers to the abstract capability provided by one layer of the OSI Basic Reference Model to the layer immediately above. Thus, the data-link layer service defined in this standard is a conceptual architectural service, independent of administrative and implementation divisions.

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 3-13: Data-link layer service definition – Type 13 elements

1 Scope

1.1 Overview

This part of IEC 61158 provides common elements for basic time-critical messaging communications between devices in an automation environment. The term "time-critical" is used to represent the presence of a time-window, within which one or more specified actions are required to be completed with some defined level of certainty. Failure to complete specified actions within the time window risks failure of the applications requesting the actions, with attendant risk to equipment, plant and possibly human life.

This standard defines in an abstract way the externally visible service provided by the Type 13 fieldbus data-link layer in terms of

a) the primitive actions and events of the service;

b) the parameters associated with each primitive action and event, and the form which they take; and

c) the interrelationship between these actions and events, and their valid sequences.

The purpose of this standard is to define the services provided to

- the Type 13 fieldbus application layer at the boundary between the application and data-link layers of the fieldbus reference model, and
- systems management at the boundary between the data-link layer and systems management of the fieldbus reference model.

1.2 Specifications

The principal objective of this standard is to specify the characteristics of conceptual data-link layer services suitable for time-critical communications, and thus supplement the OSI Basic Reference Model in guiding the development of data-link protocols for time-critical communications. A secondary objective is to provide migration paths from previously-existing industrial communications protocols.

This specification may be used as the basis for formal DL-Programming-Interfaces. Nevertheless, it is not a formal programming interface, and any such interface will need to address implementation issues not covered by this specification, including

a) the sizes and octet ordering of various multi-octet service parameters, and

b) the correlation of paired request and confirm, or indication and response, primitives.

1.3 Conformance

This standard does not specify individual implementations or products, nor do they constrain the implementations of data-link entities within industrial automation systems.

There is no conformance of equipment to this data-link layer service definition standard. Instead, conformance is achieved through implementation of the corresponding data-link protocol that fulfills the Type 13 data-link layer services defined in this standard.

2 Normative references

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

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

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

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

3 Terms, definitions, symbols, abbreviations and conventions

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

3.1 Reference model terms and definitions

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

3.1.1 DL-address [7498-3]

3.1.2 DL-address-mapping [7498-1]

3.1.3 called-DL-address [7498-3]

3.1.4 calling-DL-address [7498-3]

3.1.5 centralized multi-end-point-connection [7498-1]

3.1.6 DL-connection [7498-1]

3.1.7 DL-connection-end-point [7498-1]

3.1.8 DL-connection-end-point-identifier [7498-1]

3.1.9 DL-connection-mode transmission [7498-1]

3.1.10 DL-connectionless-mode transmission [7498-1]

3.1.11 correspondent (N)-entities [7498-1]
correspondent DL-entities (N=2)
correspondent Ph-entities (N=1)

3.1.12 DL-duplex-transmission [7498-1]

3.1.13 (N)-entity [7498-1]
DL-entity (N=2)
Ph-entity (N=1)

3.1.14 DL-facility [7498-1]

3.1.15 flow control [7498-1]

3.1.16 (N)-layer [7498-1]
DL-layer (N=2)
Ph-layer (N=1)

3.1.17 layer-management [7498-1]

3.1.18 DL-local-view [7498-3]

3.1.19 DL-name [7498-3]

3.1.20 naming-(addressing)-domain [7498-3]

3.1.21 peer-entities [7498-1]

3.1.22 primitive name [7498-3]

3.1.23 DL-protocol [7498-1]

3.1.24 DL-protocol-connection-identifier [7498-1]

3.1.25 DL-protocol-data-unit [7498-1]

3.1.26 DL-relay [7498-1]

3.1.27 reset [7498-1]

3.1.28 responding-DL-address [7498-3]

3.1.29 routing [7498-1]

3.1.30 segmenting [7498-1]

3.1.31 (N)-service [7498-1]
DL-service (N=2)
Ph-service (N=1)

3.1.32 (N)-service-access-point [7498-1]
DL-service-access-point (N=2)
Ph-service-access-point (N=1)

3.1.33 DL-service-access-point-address [7498-3]

3.1.34 DL-service-connection-identifier [7498-1]

3.1.35 DL-service-data-unit [7498-1]

3.1.36 DL-simplex-transmission [7498-1]

3.1.37 DL-subsystem [7498-1]

3.1.38 systems-management [7498-1]

3.1.39 DLS-user-data [7498-1]

3.2 Service convention terms and definitions

This standard also makes use of the following terms defined in ISO/IEC 10731 as they apply to the data-link layer:

3.2.1 acceptor

3.2.2 asymmetrical service

3.2.3 confirm (primitive); requestor.deliver (primitive)

3.2.4 deliver (primitive)

3.2.5 DL-confirmed-facility

3.2.6 DL-facility

3.2.7 DL-local-view

3.2.8 DL-mandatory-facility

3.2.9 DL-non-confirmed-facility

3.2.10 DL-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 Data-link service terms and definitions

3.3.1

application process
application layer task

3.3.2

async-only CN
CN that is accessed only by polling

3.3.3

asynchronous period
second part of the Type 13 cycle, starting with a start of asynchronous (SoA) frame

3.3.4

basic Ethernet mode
mode that provides legacy Ethernet communication

3.3.5

continuous
communication class where isochronous communication takes place every cycle (the opposite to multiplexed)

3.3.6

controlled node
network node without the ability to manage the SCNM mechanism

3.3.7

cycle time
time between two consecutive start of cyclic (SoC) frames

NOTE The Cycle Time includes the time for data transmission and some idle time before the beginning of the next cycle.

3.3.8

DLCEP-address
DL-address which designates either

a) one peer DL-connection-end-point, or

b) one multi-peer publisher DL-connection-end-point and implicitly the corresponding set of subscriber DL-connection-end-points where each DL-connection-end-point exists within a distinct DLSAP and is associated with a corresponding distinct DLSAP-address

3.3.9

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

3.3.10

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

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

3.3.11

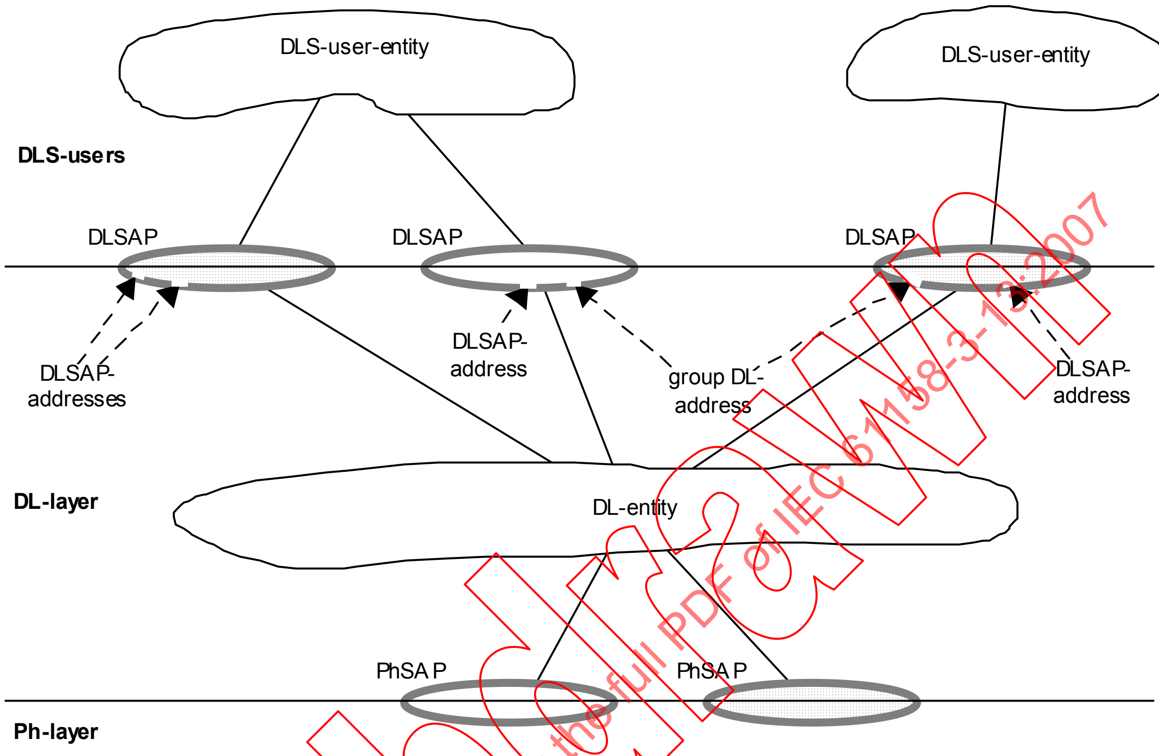
DL(SAP)-address
either an individual DLSAP-address, designating a single DLSAP of a single DLS-user, or a group DL-address potentially designating multiple DLSAPs, each of a single DLS-user.

NOTE 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.

3.3.12

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

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



NOTE 1 DLSAPs and PhSAPs are depicted as ovals spanning the boundary between two adjacent layers.

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

NOTE 3 A single 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

3.3.13

frame
denigrated synonym for DLPDU

3.3.14

isochronous data
data which is transmitted every cycle (or every n^{th} cycle in case of multiplexed isochronous data)

3.3.15

isochronous period
period within each cycle that offers deterministic operation through being reserved for the exchange of (continuous or multiplexed) isochronous data

3.3.16

legacy Ethernet
Ethernet as standardized in ISO/IEC 8802-3 (non-deterministic operation in non-time-critical environments)

3.3.17

managing node
node that can manage the SCNM mechanism

3.3.18

multiplexed
communication class where cyclic communication takes place in such a way that ***m*** nodes are served in ***s*** cycles (an alternative to continuous)

NOTE ***m***=***s***=1 is a special case for multiplexed nodes, which behaves like *continuous* but is still *multiplexed*. There are two node classes: *continuous* and *multiplexed*. Each node is a member of exactly one of these classes.

3.3.19

multiplexed timeslot
timeslot assigned to multiplexed isochronous data and shared among multiple nodes

3.3.20

multipoint connection
connection from one node to many nodes

NOTE Multipoint connection allows data transfer from a single publisher to many subscriber nodes.

3.3.21

multi-peer DLC
centralized multi-end-point DL-connection offering DL-duplex-transmission between a single distinguished DLS-user known as the publisher or publishing DLS-user, and a set of peer but undistinguished DLS-users known collectively as the subscribers or subscribing DLS-users, where the publishing DLS-user can send to the subscribing DLS-users as a group (but not individually), and the subscribing DLS-users can send to the publishing DLS-user (but not to each other).

3.3.22

NetTime
clock time of the MN as distributed to all CNs by the SoC frame

3.3.23

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

3.3.24

node
single DL-entity as it appears on one local link

3.3.25

PollRequest
frame which is used in the isochronous part of a communications cycle

3.3.26

PollResponse
frame which is used in the isochronous part of a communications cycle to respond to a PollRequest frame

3.3.27

process data object
object for isochronous data exchange between nodes

3.3.28

protocol
convention about the data formats, time sequences, and error correction in the data exchange of communication systems

3.3.29

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

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

3.3.30

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

3.3.31

service data object
object for asynchronous data exchange between nodes

3.3.32

slot communication network management
mechanism which ensures that there are no collisions during physical network access of any of the networked nodes, thus providing deterministic communication via legacy Ethernet

3.3.33

network cycle
basic repeating fixed interval of data exchange within a network that is subdivided into an isochronous and an asynchronous period and is organized by the MN

3.3.34

node ID
single-octet node DL-address used by the Type 13 DL-protocol

3.4 Symbols and abbreviations

3.4.1 ASnd	Asynchronous send (Type 13 frame type)
3.4.2 CN	Controlled node
3.4.3 DL-	Data-link layer (as a prefix)
3.4.4 DLC	DL-connection
3.4.5 DLCEP	DL-connection-end-point
3.4.6 DLE	DL-entity (the local active instance of the data-link layer)
3.4.7 DLL	DL-layer
3.4.8 DLPCI	DL-protocol-control-information
3.4.9 DLPDU	DL-protocol-data-unit
3.4.10 DLM	DL-management
3.4.11 DLME	DL-management entity (the local active instance of DL-management)
3.4.12 DLMS	DL-management service
3.4.13 DLS	DL-service
3.4.14 DLSAP	DL-service-access-point
3.4.15 DLSDU	DL-service-data-unit
3.4.16 FIFO	First-in first-out (queuing method)
3.4.17 MN	Managing node
3.4.18 NMT	Network management
3.4.19 OSI	Open systems interconnection
3.4.20 PDO	Process data object
3.4.21 Ph-	Physical layer (as a prefix)
3.4.22 PhE	Ph-entity (the local active instance of the physical layer)
3.4.23 PhL	Ph-layer
3.4.24 PReq	PollRequest frame type
3.4.25 PRes	PollResponse frame type
3.4.26 RTE	Real time Ethernet
3.4.27 SCNM	Slot communication network management
3.4.28 SDO	Service data object
3.4.29 SoA	Start of asynchronous frame type
3.4.30 SoC	Start of cyclic frame type

3.5 Common conventions

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

The service model, service primitives, and time-sequence diagrams used are entirely abstract descriptions; they do not represent a specification for implementation.

Service primitives, used to represent service user/service provider interactions (see ISO/IEC 10731), convey parameters that indicate information available in the user/provider interaction.

This standard uses a tabular format to describe the component parameters of the DLS primitives. The parameters that apply to each group of DLS primitives are set out in tables throughout the remainder of this standard. Each table consists of up to six columns, containing the name of the service parameter, and a column each for those primitives and parameter-transfer directions used by the DLS:

- The request primitive's input parameters;
- The request primitive's output parameters;
- The indication primitive's output parameters;
- The response primitive's input parameters; and
- The confirm primitive's output parameters.

NOTE The request, indication, response and confirm primitives are also known as requestor.submit, acceptor.deliver, acceptor.submit, and requestor.deliver primitives, respectively (see ISO/IEC 10731).

One parameter (or part of it) is listed in each row of each table. Under the appropriate service primitive columns, a code is used to specify the type of usage of the parameter on the primitive and parameter direction specified in the column:

M Parameter: mandatory for the primitive.

U Parameter: a User option, and may or may not be provided depending on the dynamic usage of the DLS-user. When not provided, a default value for the parameter is assumed.

C Parameter is conditional upon other parameters or upon the environment of the DLS-user.

(Blank) Parameter is never present.

Some entries are further qualified by items in brackets. These may be

a) a parameter-specific constraint

(=) indicates that the parameter is semantically equivalent to the parameter in the service primitive to its immediate left in the table.

b) an indication that some note applies to the entry

(n) indicates that the following note n contains additional information pertaining to the parameter and its use.

In any particular interface, not all parameters need be explicitly stated. Some may be implicitly associated with the DLSAP at which the primitive is issued.

In the diagrams which illustrate these interfaces, dashed lines indicate cause-and-effect or time-sequence relationships, and wavy lines indicate that events are roughly contemporaneous.

3.6 Additional Type 13 conventions

In the diagrams which illustrate the DLS and DLM interfaces, dashed lines indicate cause-and-effect or time-sequence relationships between actions at different stations, while solid lines with arrows indicate cause-and-effect time-sequence relationships which occur within the DLE-provider at a single station.

The following notation, a shortened form of the primitive classes defined in 3.5, is used in the figures and tables.

req	request primitive
ind	indication primitive
cnf	confirm primitive (confirmation)
res	Response primitive

4 Data-link service and concept

4.1 Overview

The Type 13 services extend Ethernet according to the ISO/IEC 8802-3 standard with mechanisms to transfer data with predictable timing and precise synchronization. The communication services support timing demands typical for high-performance automation and motion applications. They do not change basic principles of ISO/IEC 8802-3, but extend it towards RTE. Thus it is possible to leverage and continue to use any standard Ethernet silicon, infrastructure component or test and measurement equipment like a network analyzer.

This standard specifies Type 13 communication services.

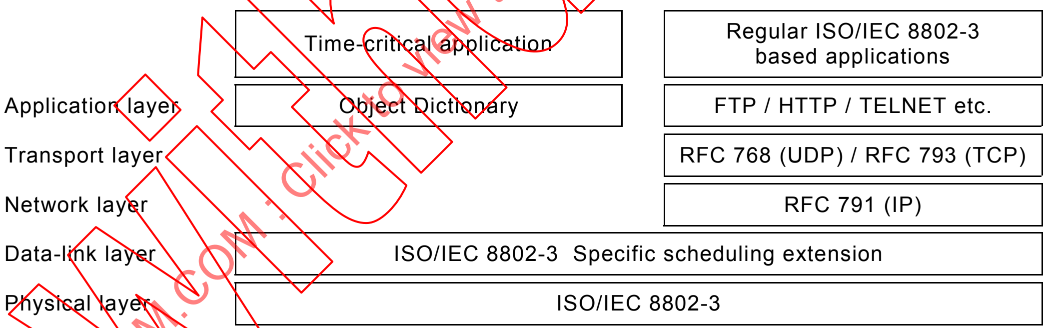


Figure 2 – Type 13 communication architecture

This standard specifies the data-link services that are the extension part of the ISO/IEC 8802-3-based data-link layer.

4.1.1 Types and classes of data-link layer service

A Type 13 data link layer provides the following services:

- Isochronous-data transfer service to send an receive isochronous data.

NOTE 1 Isochronous data transfer service is typically used for the exchange of time critical data (real-time data).

- Asynchronous-data transfer. Different message types are provided:
  - Service-data transfer to access the entries of the object dictionary.
  - Unspecified-data transfer to communicate via legacy Ethernet frames.
  - Status-data transfer for requesting the current status and detailed error information of a node.

— Ident-data transfer to identify inactive nodes and/or to query the identification data of a node.

— NMT-command transfer providing network management functions.

NOTE 2 Asynchronous data transfer is used for the exchange of non time-critical data.

- Exception-signaling transfer: The CNs are able to signal exceptions to the MN.
- NMT-status transfer providing network management data to all nodes.

All data transfers are unconfirmed, i.e. there is no confirmation that sent data has been received. To maintain deterministic behavior, protecting the isochronous data is neither necessary nor desired. Asynchronous data is to be protected by higher protocol layers.

4.1.1.1 Primitive of the isochronous-data service

The sequence of primitives for the isochronous-data service is shown in Figure 3.

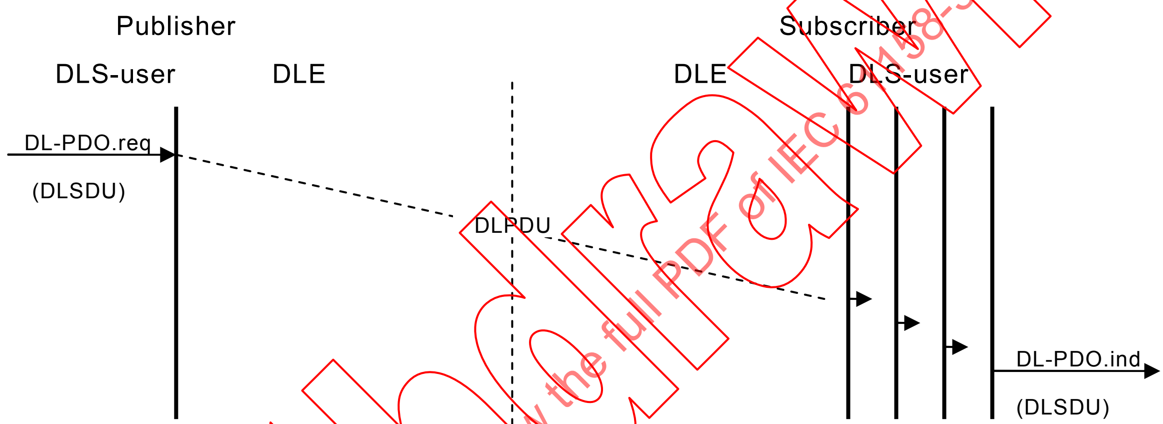


Figure 3 – Sequence diagram of isochronous-data service

The publisher DLS-user prepares a DLSDU for a single subscribed DLS-user, or for all subscribed DLS-users. The DLSDU is passed to the local DLE via the DLS interface by means of a DL-PDO request primitive. The DLE accepts the service request and tries to send the data to the subscribed DLE or to all subscribed DLEs.

The receiving DLE(s) attempt to deliver the received DLSDU to the specified DLS-user(s).

There is no confirmation of correct receipt at the remote DLEs or of delivery to the intended DLS-user(s); acknowledgements do not occur. When the DLSDU is transmitted, it reaches all subscribed DLEs approximately concurrently (ignoring signal propagation delays). Each addressed DLE that has received the data DLPDU error-free passes the DLSDU and associated addressing information to the local DLS-user by means of a DL-PDO indication primitive.

4.1.1.2 Primitive of the asynchronous-data service

4.1.1.2.1 Service-data service

The sequence of primitives for the service-data service is shown in Figure 4.

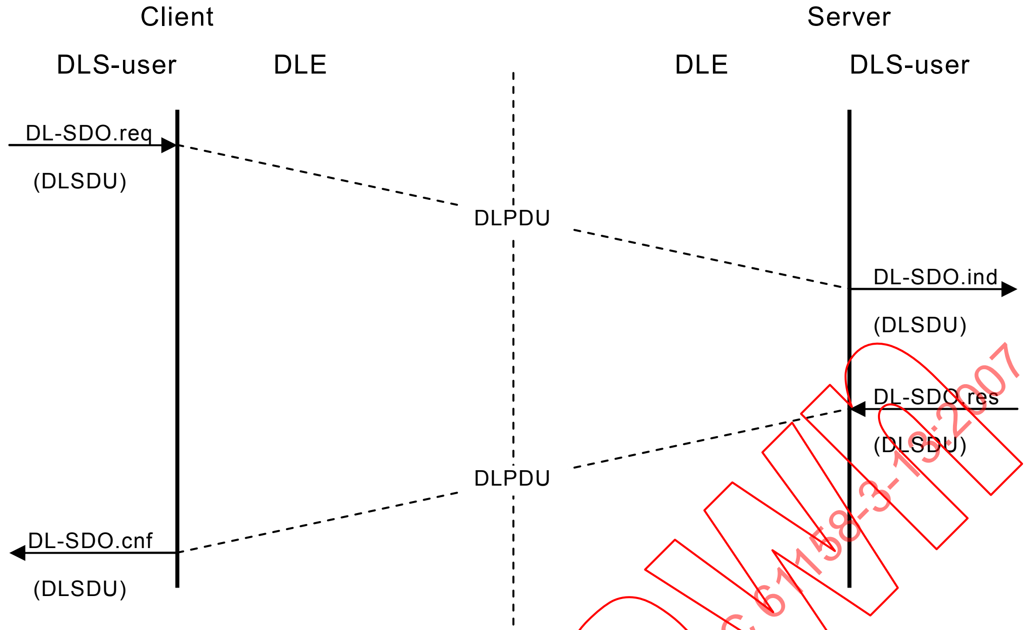


Figure 4 – Sequence diagram of service-data service

The client DLS-user prepares a DLSDU for the server DLS-user and passes it to the local DLE (DL entity) as the DLSDU parameter of a DL-SDO request primitive. The client DLE accepts the service request, forms an appropriate DLPDU containing the DLSDU, and tries to send the DLPDU to the server DLE.

Upon receiving the data DLPDU error-free, the server DLE passes the DLSDU and associated information to the local DLS-user by means of a DL-SDO indication primitive.

For acknowledgement and for upload purpose, the server prepares a DLSDU for the client DLS-user and passes it to the local DLE as the DLSDU parameter of a DL-SDO response primitive. The server DLE accepts the service response, forms an appropriate DLPDU containing the DLSDU, and tries to send the DLPDU to the client DLE.

Upon receiving the acknowledge / upload data DLPDU error-free, the client DLE passes the DLSDU and associated information to the local DLS-user by means of a DL-SDO confirmation primitive.

As the Type 13 uses unconfirmed services on the data link layer, no time limit is checked during the transfer.

4.1.1.2.2 Unspecified-data transfer

The sequence of primitives on unspecified-data transfer (UDT) is shown in Figure 5.

DL-UDT request and DL-UDT indication correspond to the MA_DATA request and MA_DATA indication defined by ISO/IEC 8802-3 respectively.

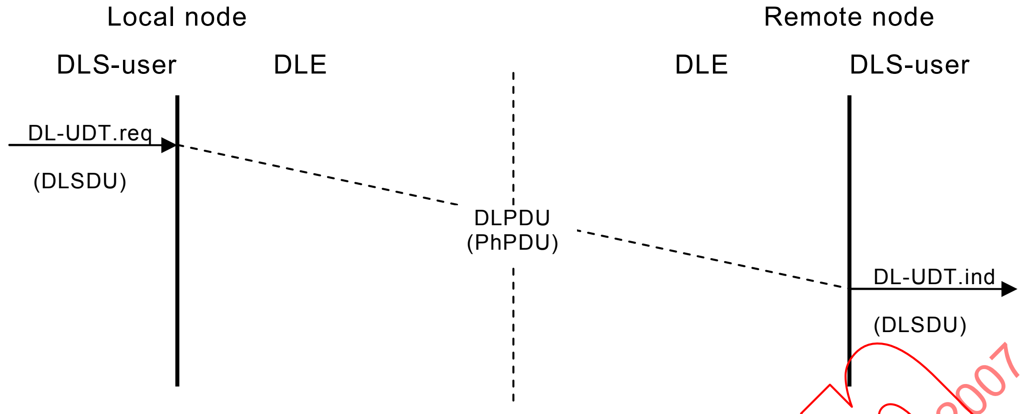


Figure 5 – Sequence diagram of an unspecified-data transfer service

4.1.1.2.3 Status-data transfer

The sequence of primitives on status-data transfer is shown in Figure 6.

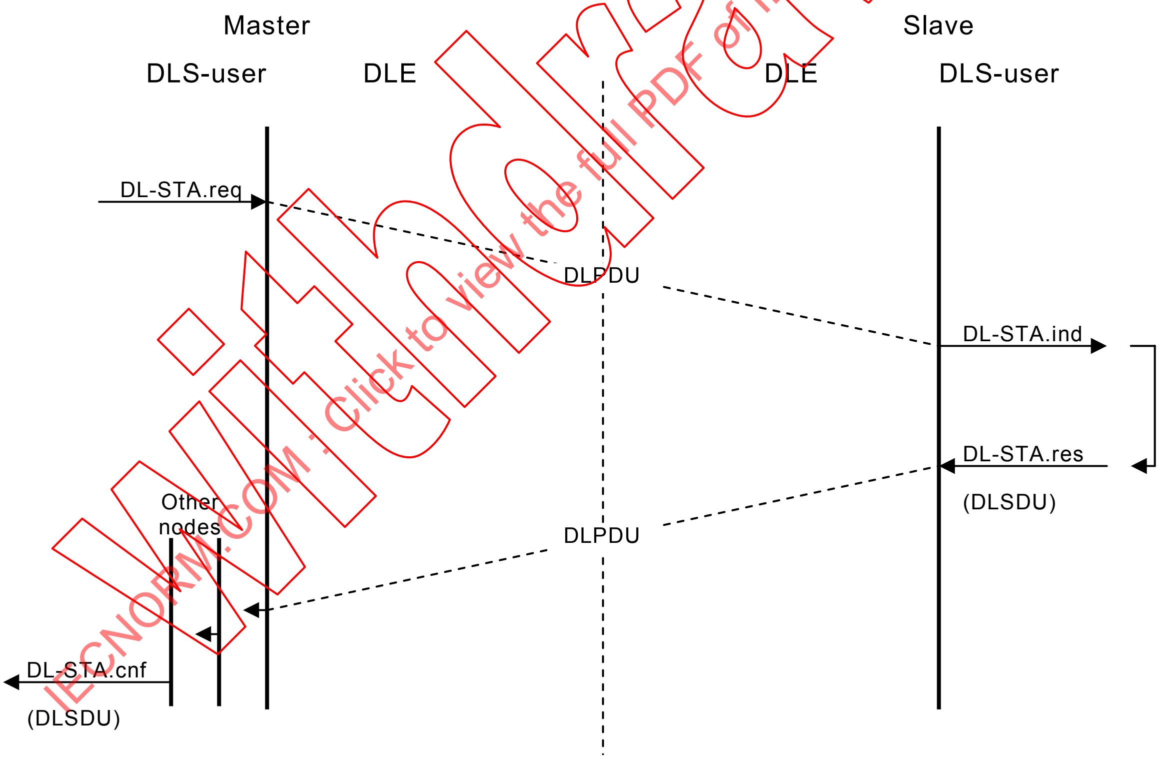


Figure 6 – Sequence diagram of a status-data transfer service

The master DLS-user requests a status-data frame from a slave node with a DL-STA request primitive, requesting data from the remote DLS-user.

Upon receiving the data DLPDU error-free, the slave DLE forms a local DL-STA indication primitive and passes it to the DLS-user. The slave DLS-user prepares a DLSDU for the master DLS-user and passes it to the local DLE as the DLSDU parameter of a DL-STA response primitive. The slave DLS-user is responsible for having prepared a valid DLSDU, ready for transmission by the slave DLE.

When a reply DLPDU is received by either the master DLS-user or any other node, the DLE passes the conveyed DLSDU to the local DLS-user by means of a DL-STA confirmation primitive.

As the Type 13 uses unconfirmed services on the data link layer, no time limit is checked during the transfer.

4.1.1.2.4 Ident-data transfer

The sequence of primitives on ident-data transfer is shown in Figure 7.

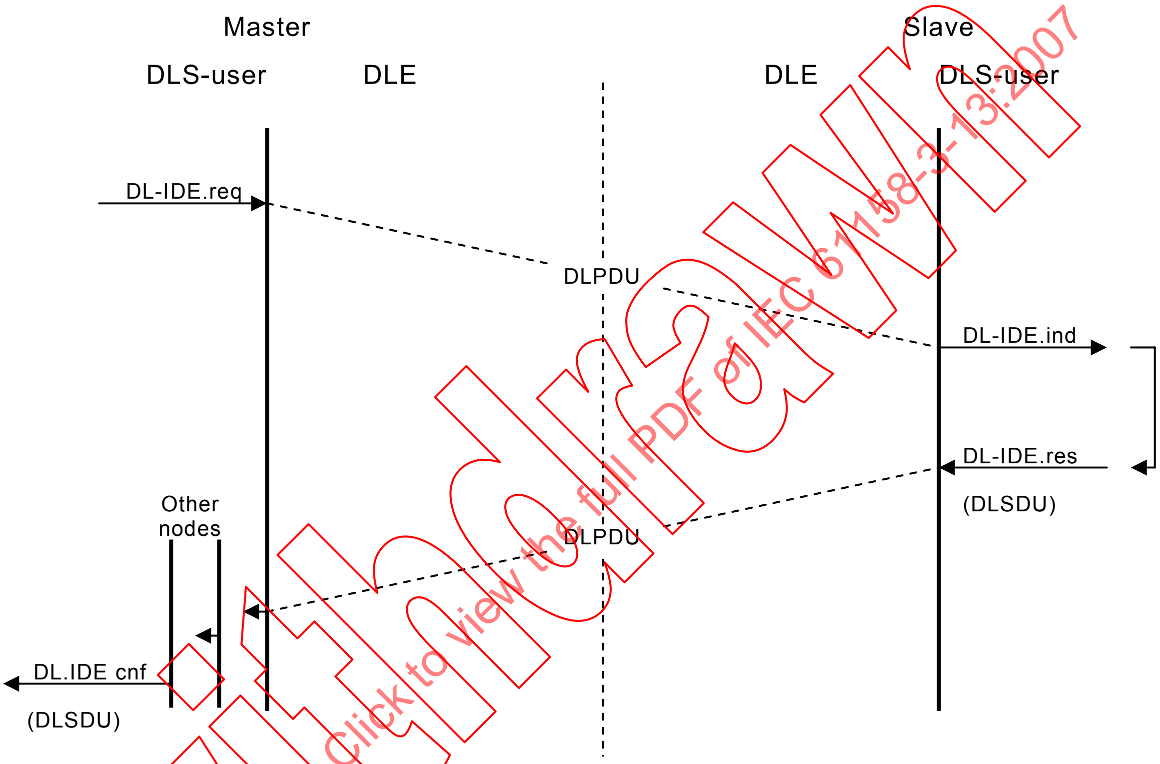


Figure 7 – Sequence diagram of an ident-data transfer service

The master DLS-user requests a ident-data frame from a slave node with a DL-IDE request primitive, requesting data from the remote DLS-user.

Upon receiving the data DLPDU error-free, the slave DLE forms a local DL-IDE indication primitive and passes it to the DLS-user. The slave DLS-user prepares a DLSDU for the master DLS-user and passes it to the local DLE as the DLSDU parameter of a DL-IDE response primitive. The slave DLS-user is responsible for having prepared a valid DLSDU, ready for transmission by the slave DLE.

When a reply DLPDU is received by either the master DLS-user or any other node, the DLE passes the conveyed DLSDU to the local DLS-user by means of a DL-IDE indication primitive.

As Type 13 uses unconfirmed services on the data link layer, no time limit is checked during the transfer.

4.1.1.2.5 NMT-command transfer

The sequence of primitives on NMT-command transfer is shown in Figure 8.

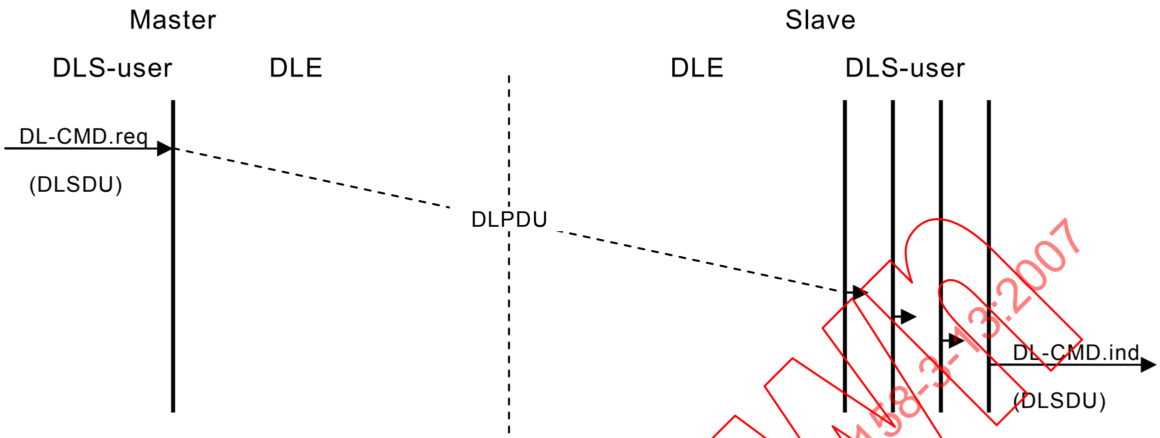


Figure 8 – Sequence diagram of an NMT-command transfer service

The master DLS-user prepares a DLSDU for a single slave DLS-user, for a group of slave DLS-users, or for all slave DLS-users. The DLSDU is passed to the local DLE via the DLS interface by means of a DL-CMD request primitive. The DLE accepts the service request and tries to send the data to the slave DLE or to all slave DLEs.

The receiving DLE(s) attempt to deliver the received DLSDU to the specified DLS-user(s).

There is no confirmation of correct receipt at the remote DLEs or of delivery to the intended DLS-user(s); acknowledgements do not occur. When the DLSDU is transmitted, it reaches all slave DLEs approximately concurrently (ignoring signal propagation delays). Each addressed slave DLE that has received the data DLPDU error-free passes the DLSDU and associated information to the local DLS-user by means of a DL-CMD indication primitive.

4.1.1.3 Exception-signaling transfer

The sequence of primitives on exception-signaling is shown in Figure 9.

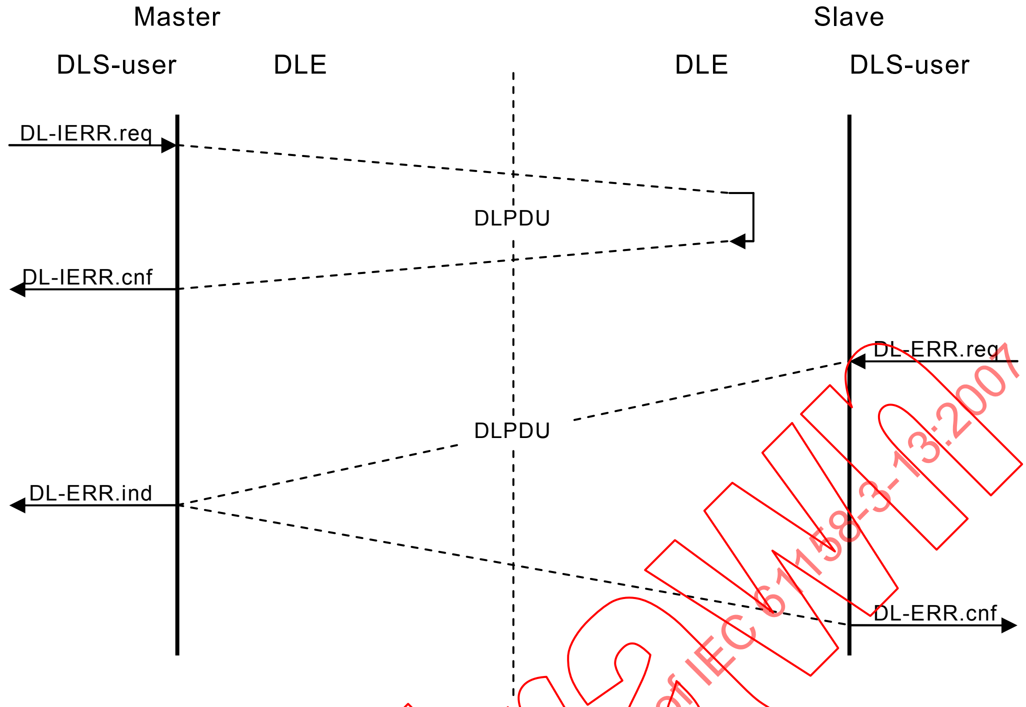


Figure 9 – Sequence diagram of an exception-signaling service

The master DLS-user prepares a DLSDU for a single slave DLS-user for initialization of the exception signaling. The DLSDU is passed to the local DLE via the DLS interface by means of a DL-IERR request primitive. The DLE accepts the service request and sends the data to the slave DLE.

The receiving DLE attempts to initialize his own exception signaling system. No signaling to the DLS-user is performed. DLE internally, the DLE confirms the receipt of the exception initialization signal by response with an exception acknowledge signal.

When an error-free acknowledgement DLPDU is received, the local DLE passes a completion status to the local DLS-user by means of a DL-IERR confirm primitive.

For exception signaling, the slave DLS-user prepares a DLSDU for the master DLS-user. The DLSDU is passed to the local DLE via the DLS interface by means of a DL-ERR request primitive. The DLE accepts the service request and tries to send the data to the master DLE.

Upon receiving the data DLPDU error-free, the master DLE forms a local DL-ERR indication primitive and passes it to the DLS-user. DLE internally, the DLE confirms the receipt of the exception signal by response with an acknowledge signal.

When an error-free acknowledgement DLPDU is received, the local DLE passes a completion status to the local DLS-user by means of a DL-ERR confirm primitive.

The master of the exception signaling system is the managing node (MN), which initializes the exception system on each CN at startup. Occurring errors are signaled by the CN via the exception signaling system to the MN. Exception signaling is done with a single data bit.

4.1.1.4 NMT-status transfer

The sequence of primitives on NMT-status transfer is shown in Figure 10.

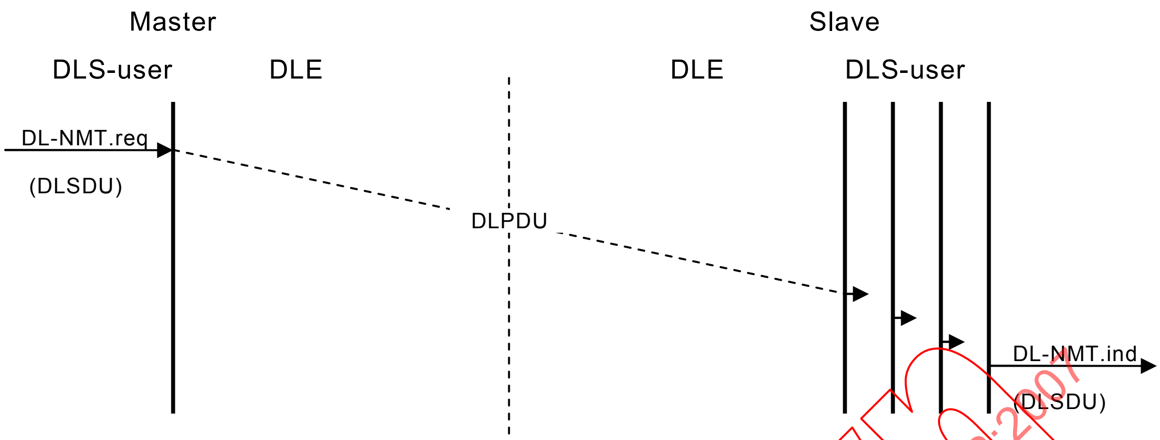


Figure 10 – Sequence diagram of a NMT-status transfer service

The master DLS-user prepares a DLSDU for all slave DLS-users. The DLSDU is passed to the local DLE via the DLS interface by means of a DL-NMT request primitive. The DLE accepts the service request and tries to send the data to the slave DLE or to all slave DLEs. It uses the information also for internally state machine setup.

The receiving DLE(s) attempt to deliver the received DLSDU to the specified DLS-user(s).

There is no confirmation of correct receipt at the remote DLEs or of delivery to the intended DLS-user(s); acknowledgements do not occur. When the DLSDU is transmitted, it reaches all slave DLEs approximately concurrently (ignoring signal propagation delays). Each addressed slave DLE that has received the data DLPDU error-free passes the DLSDU and associated information to the local DLS-user by means of a DL-NMT indication primitive.

4.1.2 Addressing

Each DL-entity on the link is designated by a DL-address. The range of individual DL-addresses is limited, from 0 to a maximum of 255. Table 1 shows the Node ID assignment.

The DL-address 255 is used for broadcast and multicast messages.

The DL-address 240 is permanently assigned to the MN. A node set to the node ID 240 operates as the MN, if the node has MN functionality. Devices with pure CN function cannot be assigned the node ID 240. Node IDs 1-239 may be used for the CNs.

NOTE The node ID is either configured by the application process or is set on the device (e.g. using address switches).

Table 1 – Type 13 node ID assignment

(individual) DL-address Type 13 Node ID	Description
0	Invalid
1..239	Regular Type 13 CNs
240	Type 13 MN
241..250	Reserved
255	Type 13 broadcast

4.2 Detailed description of isochronous-data services

4.2.1 General

This DL service provides unconfirmed data transfers between pre-established point-to-point, or point-to-multipoint DLCEPs.

4.2.2 Sequence of primitives

The isochronous data service primitives and the parameters are summarized in Table 2, the primitive sequence is shown in Figure 3.

Table 2 – Primitives and parameters used on the isochronous data service

Function	Location	Primitive	Direction	Parameters
Transmit isochronous-data	Publisher	DL-PDO.req	To DLE	D_addr DLSDU
Receive isochronous-data	Subscriber	DL-PDO.ind	From DLE	S_addr D_addr DLSDU
NOTE In this table, time increases from top to bottom.				

4.2.3 Transmit / receive isochronous-data

4.2.3.1 Function

This service permits a local DLS-user to transfer a DLSDU to a single subscribed station (Unicast), or to all other subscribed stations (Broadcast) at the same time. At each addressed station this DLSDU, if the respective DLPDU is received error-free, is delivered to a single local DLS-user (Unicast), or to all local DLS-users (Broadcast). There is no confirmation to the sending DLS-user that such an intended delivery has taken place.

4.2.3.2 Types of primitives and parameters

4.2.3.2.1 General

Table 3 indicates the parameters of transmit / receive isochronous-data service.

Table 3 – Transmit /Receive isochronous-data primitives and the parameters

DL-PDO	Request	Indication
Parameter name	Input	Output
S_addr		M (=)
D_addr	M	M (=)
DLSDU	M	M (=)

4.2.3.2.2 S_addr

The S_addr (source-address) parameter specifies the DL-address of the published DLE.

4.2.3.2.3 D_addr

The D_addr (destination-address) parameter specifies the DL-address of the subscribed DLE. The value 255, used for broadcast message, is used by CNs and once per Type 13 cycle by the MN.

NODE: The MN must send a dedicated PDO frame to every configured and active node, which correspondents to the PReq frame. The accessed node responds its PDO frame via a broadcast to all nodes, which correspondents to the PRes frame. The PReq / PRes procedure is repeated for each configured and active isochronous CN. When all configured and active isochronous CNs have been processed, the MN may be sent a multicast PRes frame to all nodes. This frame is dedicated to transfer data relevant for groups of CNs.

4.2.3.2.4 DLSDU

This parameter specifies the information that is transferred by buffer transfer from the local DLE as a publisher to the remote multi-peer DLEs as subscribers.

4.3 Detailed description of asynchronous-data service

4.3.1 Service-data transfer

4.3.1.1 General

This DL service provides a relationship between a single client and a single server. A client issues a request (upload/download) thus triggering the server to perform a certain task. After finishing the task the server answers the request.

4.3.1.2 Sequence of primitives

The service-data transfer service primitives and the parameters are summarized in Table 4, the primitive sequence is shown in Figure 4.

Table 4 – Primitives and parameters used on service data transfer service

Function	Location	Primitive	Direction	Parameters
Transmit client request to server	Client	DL-SDO.req	To DLE	C_addr S_addr SDO_Prio DLSDU
Receive client request from	Server	DL-SDO.ind	From DLE	C_addr S_addr DLSDU
Transmit server response to client	Server	DL-SDO.res	To DLE	C_addr S_addr SDO_Prio DLSDU
Receive server response	Client	DL-SDO.cnf	From DLE	C_addr S_addr DLSDU
NOTE In this table, time increases from top to bottom.				

4.3.1.3 Transmit / receive service-data

4.3.1.3.1 Function

DL-SDO request allows the DLS-user to transfer data of the corresponding DLS-user buffer to the send_buffer of the local DLE where the DLE is the client.

With DL-SDO indication the server receives the transferred data from the client.

In the case of a necessary response, the client uses the DL-SDO response to transfer data of the corresponding DLS-user buffer to the send-buffer of the local DLE.

With DL-SDO confirmation the client receives the transferred data from the server.

According to the load of the asynchronous slot, a time delay between request and indication is possible.

The data transfer is an unconfirmed service. The DLS-user is responsible for managing the correct data flow.

4.3.1.3.2 Types of primitives and parameters

4.3.1.3.2.1 General

Table 5 indicates the parameters of transmit service-data to server service.

Table 5 – Transmit / Receive service-data primitives and the parameters

DL-SDO	Request	Indication	Response	Confirmation
Parameter name	Input	Output	Input	Output
C_addr	M	M (=)	M (=)	M (=)
S_addr	M	M (=)	M (=)	M (=)
SDO_Prio	U		U	
DLSDU	M	M (=)	M (=)	M (=)

4.3.1.3.2.2 C_addr

The C_addr (client-address) parameter specifies the DL-address of the client DLE.

4.3.1.3.2.3 S_addr

The S_addr (server-address) parameter specifies the DL-address of the server DLE.

4.3.1.3.2.4 SDO_Prio

The SDO_Prio parameter specifies the priority of the frame in the asynchronous send queue.

4.3.1.3.3 DLSDU

This parameter specifies the DLS-user data that is transferred by the DLE.

4.3.2 Unspecified-data transfer

4.3.2.1 General

This DL service provides unconfirmed data transfers between pre-established point-to-point DLCEPs.

4.3.2.2 Sequence of primitives

The unspecified-data service primitives and the parameters are summarized in Table 6, the primitive sequence is shown in Figure 5.

Table 6 – Primitives and parameters used on the unspecified-data service

Function	Location	Primitive	Direction	Parameters
Transmit unspecified-data	Local	DL-UDT.req	To DLE	S_addr D_addr UDT_Prio DLSDU
Receive unspecified-data	Remote	DL-UDT.ind	From DLE	S_addr D_addr DLSDU
NOTE In this table, time increases from top to bottom.				

4.3.2.3 Transmit / Receive unspecified-data

4.3.2.3.1 Function

This service permits a local DLS-user to transfer a DLSDU to a single subscribed station. At the addressed station this DLSDU, if the respective DLPDU is received error-free, is delivered to the local DLS-user. There is no confirmation to the sending DLS-user that such an intended delivery has taken place.

4.3.2.3.2 Types of primitives and parameters

4.3.2.3.2.1 General

Table 7 indicates the parameters of transmit / receive unspecified-data service.

Table 7 – Transmit / receive unspecified-data primitives and the parameters

DL-UDT	Request	Indication
Parameter name	Input	Output
S_addr	U	M (=)
D_addr	M	U (=)
UDT_Prio	U	
DLSDU	M	M (=)

4.3.2.3.2.2 S_addr

The S_addr (source-address) parameter specifies the DL-address of the local DLE.

4.3.2.3.2.3 D_addr

The D_addr (destination-address) parameter specifies the DL-address of the remote DLE.

4.3.2.3.2.4 UDT_Prio

The UDT_Prio parameter specifies the priority of the frame in the asynchronous send queue.

4.3.2.3.3 DLSDU

This parameter specifies the DLS-user data that is transferred by the DLE.

4.3.3 Status-data transfer

4.3.3.1 General

This DL service provides a single master slave relationship. A master issue a request (status-frame) thus triggers the slave to provide the data upon receiving of an indication primitive. The Slave responses with the status DLSDU to the master and all active nodes.

4.3.3.2 Sequence of primitives

The status-data transfer service primitives and the parameters are summarized in Table 8, the primitive sequence is shown in Figure 6.

Table 8 – Primitives and parameters used on status-data transfer service

Function	Location	Primitive	Direction	Parameters
Request status response from slave	Master	DL-STA.req	To DLE	S_addr
Receive master request and prepare status response	Slave	DL-STA.ind	From DLE	S_addr
Transmit status response to master	Slave	DL-STA.res	To DLE	DLSDU
Receive status response from slave	Master	DL-STA.cnf	From DLE	S_addr DLSDU
NOTE In this table, time increases from top to bottom.				

4.3.3.3 Request status-data

4.3.3.3.1 Function

DL-STA request allows the DLS-user to request a status response from the slave.

With DL-STA indication the slave prepares the status and responses it with DL-STA response to the master.

With DL-STA confirmation the master and all other active nodes receive the transferred data from the slave.

According to the load of the asynchronous slot, a time delay between request and indication is possible.

4.3.3.3.2 Types of primitives and parameters

4.3.3.3.2.1 General

Table 9 indicates the parameters of status-data service.

Table 9 – Status data primitives and the parameters

DL-STA	Request	Indication	Response	Confirmation
Parameter name	Input	Output	Input	Output
S_addr	M	M (=)		M (=)
DLSDU			M	M (=)

4.3.3.3.2.2 S_addr

The S_addr (slave-address) parameter specifies the DL-address of the slave DLE, which is expected to reply with its status.

4.3.3.3.2.3 DLSDU

This parameter specifies the DLS-user data (status message) that is transferred by the DLE.

NOTE Some of the status parameters are inserted / removed by the DLL because of duplicated appearance of this information in normal frames and in the status message.

4.3.4 Ident-data transfer

4.3.4.1 General

This DL service provides a single master slave relationship. A master issues a request (Ident-frame) thus triggers the slave to provide the data upon receiving of an indication primitive. The Slave response with the ident DLSDU to the master and all active nodes.

4.3.4.2 Sequence of primitives

The ident-data transfer service primitives and the parameters are summarized in Table 10, the primitive sequence is shown in Figure 7.

Table 10 – Primitives and parameters used on ident-data transfer service

Function	Location	Primitive	Direction	Parameters
Request ident response from slave	Master	DL-IDE.req	To DLE	S_addr
Receive master request and prepare ident response	Slave	DL-IDE.ind	From DLE	S_addr
Transmit ident response to master	Slave	DL-IDE.res	To DLE	DLSDU
Receive ident response from slave	Master	DL-IDE.cnf	From DLE	S_addr DLSDU
NOTE In this table, time increases from top to bottom.				

4.3.4.3 Request ident-data

4.3.4.3.1 Function

DL-STA request allows the DLS-user to request an ident response from the slave.

With DL-STA indication the slave prepares the ident and responses it with DL-STA response to the master.

With DL-STA confirmation the master and all other active nodes receive the transferred data from the slave.

According to the load of the asynchronous slot, a time delay between request and indication is possible.

4.3.4.3.2 Types of primitives and parameters

4.3.4.3.2.1 General

Table 11 indicates the parameters of ident data service.

Table 11 – Ident data primitives and the parameters

DL-IDE	Request	Indication	Response	Confirmation
Parameter name	Input	Output	Input	Output
S_addr	M	M (=)		M (=)
DLSDU			M	M (=)

4.3.4.3.2.2 S_addr

The S_addr (slave-address) parameter specifies the DL-address of the slave DLE, which is expected to reply with its ident parameter.

4.3.4.3.2.3 DLSDU

This parameter specifies the DLS-user data (ident message) that is transferred by the DLE.

NOTE Some of the ident parameters are inserted / removed by the DLL because of duplicated appearance of this information in normal frames and in the ident message.

4.3.5 NMT-command services

4.3.5.1 General

This DL service provides unconfirmed data transfers between point-to-point, or point-to-multipoint DLCEPs.

4.3.5.2 Sequence of primitives

The NMT-command service primitives and the parameters are summarized in Table 12, the primitive sequence is shown in Figure 8.

Table 12 – Primitives and parameters used on the NMT-command service

Function	Location	Primitive	Direction	Parameters
Transmit NMT-command	Master	DL-CMD.req	To DLE	D_addr DLSDU
Receive NMT-command	Slave	DL-CMD.ind	From DLE	DLSDU
NOTE In this table, time increases from top to bottom.				

4.3.5.3 Transmit / receive NMT-command

4.3.5.3.1 Function

This service permits a local DLS-user to transfer a DLSDU to a single subscribed station (Unicast), or to all other subscribed stations (Broadcast) at the same time. At each addressed station this DLSDU, if the respective DLPDU is received error-free, is delivered to a single local DLS-user (Unicast), or to all local DLS-users (Broadcast). There is no confirmation to the sending DLS-user that such an intended delivery has taken place.

4.3.5.3.2 Types of primitives and parameters

4.3.5.3.2.1 General

Table 13 indicates the parameters of NMT-command service.

Table 13 – NMT-command primitives and the parameters

DL-CMD	Request	Indication
Parameter name	Input	Output
D_addr	M	
DLSDU	M	M (=)

4.3.5.3.2.2 D_addr

The D_addr (destination-address) parameter specifies the DL-address of the subscribed DLE. The value 255, used for broadcast message, indicates this message for all connected nodes.

4.3.5.3.2.3 DLSDU

This parameter specifies the information that is transferred by buffer transfer from the local DLE as a publisher to the remote multi-peer DLEs as subscribers.

The further differentiation between different possible NMT commands and the interpretation of the included NMT command data is in responsible of the APL.

4.4 Detailed description of exception-signaling services

4.4.1 General

This DL service provides confirmed exception-signaling between point-to-point DLCEPs.

4.4.2 Sequence of primitives

The exception-signal service primitives and the parameters are summarized in Table 14, the primitive sequence is shown in Figure 9.

Table 14 – Primitives and parameters used on the exception-signaling service

Function	Location	Primitive	Direction	Parameters
Request exception-signaling initialization	Master	DL-IERR.req	To DLE	D_addr
Confirmation of exception-signaling initialization	Master	DL-IERR.cnf	From DLE	D_addr
Request exception-signaling	Slave	DL-ERR.req	To DLE	S_addr
Exception-signaling indication	Master	DL-ERR.ind	From DLE	S_addr
Confirmation of exception-signaling	Slave	DL-ERR.cnf	From DLE	S_addr
NOTE In this table, time increases from top to bottom.				

4.4.3 Exception-signaling initialization

4.4.3.1 Function

This service is used to initialize the exception signaling system. It is accomplished on each node during system initialization.

The master requests this service with the DL-IERR request primitive. After the accomplishment of the initialization the master receives a confirmation with the DL-IERR confirmation primitive.

Only the MN shall use this service.

4.4.3.2 Types of primitives and parameters

4.4.3.2.1.1 General

Table 15 indicates the parameters of exception-signaling initialization.

Table 15 – Exception-signaling initialization primitives and the parameters

DL-IERR	Request	Confirmation
Parameter name	Input	Output
D_addr	M	M (=)

4.4.3.2.1.2 D_addr

The D_addr (destination-address) parameter specifies the DL-address of the subscribed DLE. The global address (255) for broadcast and the MN address (240) is not permitted.

4.4.4 Exception-signaling

4.4.4.1 Function

This service is used to signal an exception to the MN.

A slave requests this service with the DL-ERR request primitive. The addressed master gets an DL-ERR indication primitive. After accomplishment of the signaling the slave receives a confirmation with the DL-ERR confirmation primitive.

Only the CN shall use this service. The addressed master is always the MN.

As long as an active exception-signaling process is active, the APL shall not query further exceptions.

4.4.4.2 Types of primitives and parameters

4.4.4.2.1.1 General

Table 16 indicates the parameters of the exception-signaling service.

Table 16 – Exception signaling initialization primitives and the parameters

DL-ERR	Request	Indication	Confirmation
Parameter name	Input	Output	Output
S_addr		M	

4.4.4.2.1.2 S_addr

The S_addr (source-address) parameter specifies the DL-address of the requested DLE. The global address (255) for broadcast and the MN address (240) is not permitted.

4.5 NMT-status services

4.5.1 General

This DL service provides unconfirmed data transfers between point-to-multipoint DLCEPs.

4.5.2 Sequence of primitives

The NMT-status service primitives and the parameters are summarized in Table 17, the primitive sequence is shown in Figure 10.

Table 17 – Primitives and parameters used on the NMT-status service

Function	Location	Primitive	Direction	Parameters
Transmit NMT-status	Master	DL-NMT.req	To DLE	S_addr
Receive NMT-status	Slave	DL-NMT.ind	From DLE	S_addr NMTStatus
NOTE In this table, time increases from top to bottom.				

4.5.3 Transmit / Receive NMT status

4.5.3.1 Function

This service permits a local DLS-user to transfer a DLSDU to all other subscribed stations (Broadcast) at the same time. At each addressed station this DLSDU, if the respective DLPDU is received error-free, is delivered to all local DLS-users (Broadcast). There is no confirmation to the sending DLS-user that such an intended delivery has taken place.

This service reports the current status of the MN (source address = 240) and the CNs NMT state machine.

4.5.3.2 Types of primitives and parameters

4.5.3.2.1 General

Table 18 indicates the parameters of NMT-status service.

Table 18 – NMT-status primitives and the parameters

DL-NMT	Request	Indication
Parameter name	Input	Output
S_addr		M
NMTStatus	M	M (=)

4.5.3.2.2 S_addr

The S_addr (source-address) parameter specifies the DL-address of the published DLE.

4.5.3.2.3 NMTStatus

This parameter indicates the current NMTStatus of the corresponding node. Permitted values for this parameter are specified in IEC 61158-5-13.