

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Industrial communication networks – Fieldbus specifications –
Part 4-13: Data-link layer protocol specification – Type 13 elements**

**Réseaux de communication industriels – Spécifications des bus de terrain –
Partie 4-13: Spécification du protocole de la couche liaison de données –
Éléments de type 13**



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IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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FIELDBUS SPECIFICATIONS –****Part 4-13: Data-link layer protocol specification –
Type 13 elements**

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NOTE Combinations of protocol types are specified in IEC 61784-1 and IEC 61784-2.

International Standard IEC 61158-4-13 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This second edition cancels and replaces the first edition published in 2007. This edition constitutes a technical revision. The main changes with respect to the previous edition are listed below:

- addition of a new communication class,
- corrections and
- editorial improvements.

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

FDIS	Report on voting
65C/762/FDIS	65C/772/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.

A 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.

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

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- withdrawn;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

INTRODUCTION

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

The data-link protocol provides the data-link service by making use of the services available from the physical layer. The primary aim of this 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 4-13: Data-link layer protocol specification – Type 13 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 synchronously-starting cyclic manner, according to a pre-established schedule, and
- b) in a cyclic or acyclic asynchronous manner, as requested each cycle by each of those data-link entities.

Thus this protocol can be characterized as one which provides cyclic and acyclic access asynchronously but with a synchronous restart of each cycle.

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) procedures for giving communications opportunities to all participating DL-entities, sequentially and in a cyclic manner for deterministic and synchronized transfer at cyclic intervals up to one millisecond;
- c) procedures for giving communication opportunities available for time-critical data transmission together with non-time-critical data transmission without prejudice to the time-critical data transmission;
- d) procedures for giving cyclic and acyclic communication opportunities for time-critical data transmission with prioritized access;
- e) procedures for giving communication opportunities based on ISO/IEC 8802-3 medium access control, with provisions for nodes to be added or removed during normal operation;
- f) 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 references

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

IEC 61588, *Precision clock synchronization protocol for networked measurement and control systems*

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

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

ISO/IEC 8802-3:2000, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

ISO/IEC 10731, *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 correspondent DL-entities (N=2) correspondent Ph-entities (N=1)	[7498-1]
3.1.12	DL-duplex-transmission	[7498-1]
3.1.13	(N)-entity DL-entity (N=2) Ph-entity (N=1)	[7498-1]
3.1.14	DL-facility	[7498-1]
3.1.15	flow control	[7498-1]
3.1.16	(N)-layer DL-layer (N=2) Ph-layer (N=1)	[7498-1]
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

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

3.3.1

async-only CN

CN that is accessed only by polling

3.3.2

asynchronous period

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

3.3.3

basic Ethernet mode

mode that provides legacy Ethernet communication

3.3.4

continuous-time-triggered

communication class where isochronous communication takes place every cycle

Note 1 to entry: The data sent from MN to various CNs are packed into a PollResponse. No PollRequest to these CNs is necessary. The CNs send their PollResponse time triggered. (An alternative to continuous).

Note 2 to entry: There are three node classes: *continuous*, *multiplexed* and *continuous-time-triggered*. Each node is a member of exactly one of these classes.

3.3.5

continuous

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

Note 1 to entry: There are three node classes: *continuous*, *multiplexed* and *continuous-time-triggered*. Each node is a member of exactly one of these classes.

3.3.6

controlled node (CN)

network node without the ability to manage the SCNM mechanism

3.3.7

cycle state machine

state machine that controls the data-link layer cycle and is itself controlled by the NMT state machine which determines the current operating mode

3.3.8

cycle time

time between two consecutive start of cyclic (SoC) frames

Note 1 to entry: The Cycle Time includes the time for data transmission and some idle time before the beginning of the next cycle.

3.3.9

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

3.3.10

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

3.3.11

DLSAP

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

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

3.3.12

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

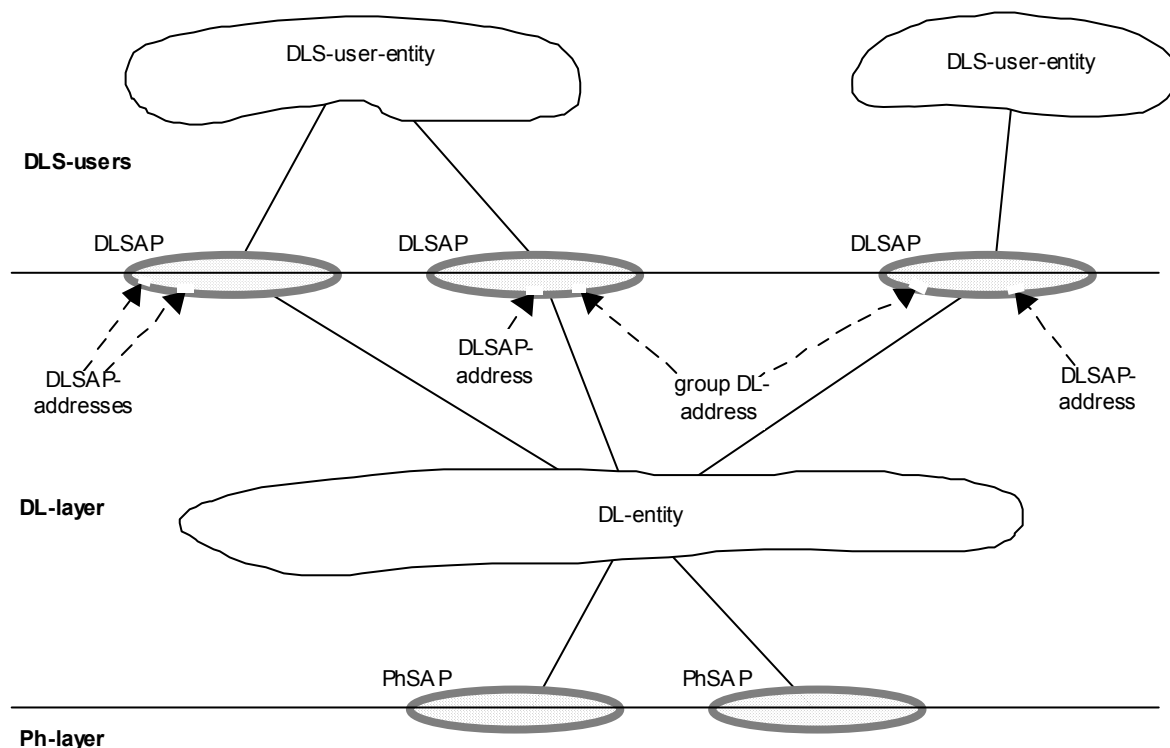
Note 1 to entry: This terminology is chosen because ISO/IEC 7498-3 does not permit the use of the term DLSAP-address to designate more than a single DLSAP at a single DLS-user.

3.3.13

(individual) DLSAP-address

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

Note 1 to entry: A single DL-entity may have multiple DLSAP-addresses associated with a single DLSAP (see Figure 1).



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

3.3.14

Type 13 fieldbus cycle

fixed time interval consecutively repeated which is organized by the MN

3.3.15

Type 13 fieldbus node ID

unique number within one Type 13 network used to address a Type 13 fieldbus node

3.3.16

frame

denigrated synonym for DLPDU

3.3.17

isochronous data

data which is transmitted every cycle (or every nth cycle in case of multiplexed isochronous data)

3.3.18

isochronous period

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

3.3.19

legacy Ethernet

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

3.3.20**managing node**

node that can manage the SCNM mechanism

3.3.21**multiplexed**

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

3.3.22**multiplexed timeslot**

timeslot assigned to multiplexed isochronous data and shared among multiple nodes

3.3.23**multipoint connection**

connection from one node to many nodes

Note 1 to entry: Multipoint connection allows data transfer from a single publisher to many subscriber nodes.

3.3.24**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)

3.3.25**NetTime**

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

3.3.26**network management**

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

3.3.27**node**

single DL-entity as it appears on one local link

3.3.28**PollRequest**

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

3.3.29**PollResponse**

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

3.3.30**process data object**

object for isochronous data exchange between nodes

3.3.31**protocol**

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

3.3.32

receiving DLS-user

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

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

3.3.33

sending DLS-user

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

3.3.34

service data object

object for asynchronous data exchange between nodes

3.3.35

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

3.4 Symbols and abbreviations

ASnd	Asynchronous send (Type 13 frame type)
ASS	Asynchronous slot scheduler
ATC	Asynchronous transmission TX/RX control
CN	Controlled node
CSM	Cycle state machine
DL-	Data-link layer (as a prefix)
DLC	DL-connection
DLCEP	DL-connection-end-point
DLE	DL-entity (the local active instance of the data-link layer)
DLL	DL-layer
DLPDU	DL-protocol-data-unit
DLM	DL-management
DLMS	DL-management service
DLS	DL-service
DLSAP	DL-service-access-point
DLSDU	DL-service-data-unit
ES	Exception signaling
FIFO	First-in first-out (queuing method)
ITC	Isochronous transmission RX/TX control
MAC	Media access control
MN	Managing node
NMT	Network management
NS	NMT signaling
OSI	Open systems interconnection
PDO	Process data object
PDU	Protocol data unit
Ph-	Physical layer (as a prefix)
PhL	Ph-layer
PhPDU	Ph-protocol-data-unit
PhS	Ph-service

PReq	PollRequest (Type 13 frame type)
PRes	PollResponse (Type 13 frame type)
SCNM	Slot communication network management
SDO	Service data object
SoA	Start of asynchronous (Type 13 frame type)
SoC	Start of cyclic (Type 13 frame type)
UDT	Unspecified-data transfer

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 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 Overview of the DL-protocol

4.1 Overview

A Type 13 fieldbus extends Ethernet according to ISO/IEC 8802-3 with mechanisms to transfer data with predictable timing and precise synchronization to meet timing demands typical for high-performance automation and motion applications. It does not change basic principles of the Fast Ethernet Standard ISO/IEC 8802-3 but extends it towards real-time Ethernet. 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.

4.2 General description

4.2.1 General

Type 13 fieldbus provides mechanisms to achieve the following.

- Transmit time-critical data in precise isochronous cycles. Data exchange is based on a publish/subscribe relationship.
- Synchronize networked nodes with high accuracy.
- Transmit less time-critical data on request asynchronously. Asynchronous data communication can be used to transfer IP-based protocols like TCP or UDP and higher layer protocols such as HTTP, FTP,...

Type 13 fieldbus manages the network traffic in a way that there are dedicated time-slots for isochronous and asynchronous data (see Figure 2). It takes care that always only one networked device gains access to the network media. Thus transmission of isochronous and asynchronous data will never interfere and precise communication timing is guaranteed. The mechanism is called slot communication network management (SCNM). SCNM is managed by one particular networked device – the Managing Node (MN) – which includes the MN functionality. All other nodes are called controlled nodes (CN).

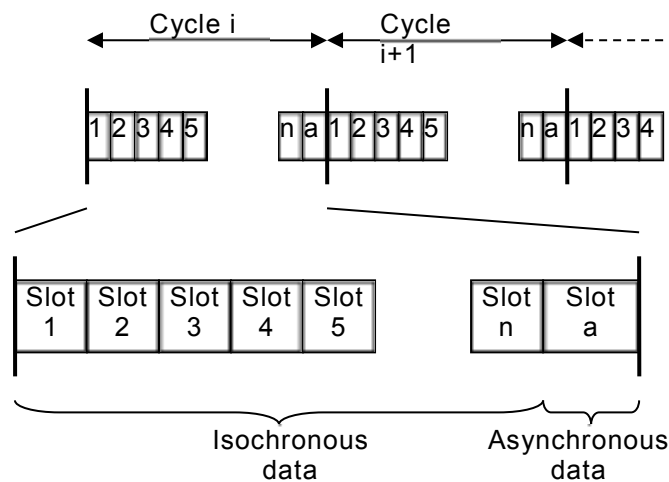


Figure 2 – Slot communication network management

Network access is managed by a master, the Type 13 fieldbus managing node (MN). A node is only being able to be granted the right to send data on the network via the MN. The central access rules preclude collisions; therefore a Type 13 network is therefore deterministic.

CNs are passive bus nodes; they only send when requested by the MN.

4.2.2 Overview of the medium access control and transmission protocol

Overview of the data frames flow on the medium is shown in Figure 3.

Data exchange between nodes occurs cyclically. It is required that the repetition occurs in a fixed interval, called Type 13 fieldbus cycle. The following time phases exist within one Type 13 fieldbus cycle.

- Isochronous phase
- Asynchronous phase
- Idle phase

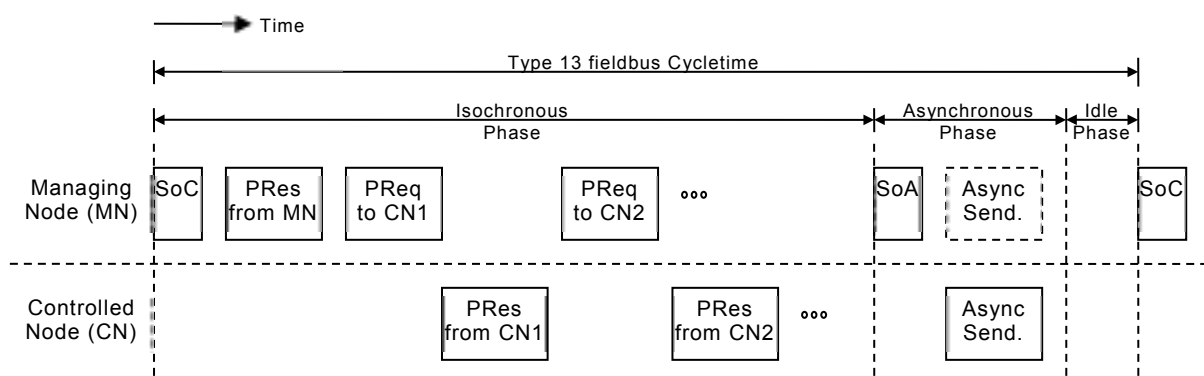


Figure 3 – Overall flow of data frames during one cycle

4.2.2.1 Isochronous phase

The DLL shall provide the opportunity of transferring data to each node in a sequential order and within a predetermined time period. At the beginning of a Type 13 fieldbus cycle, the MN shall send a SoC frame to all nodes via Ethernet multicast. The sending and receiving time of this frame is the basis for the common timing of all the nodes. Only the SoC frame

generated on a periodic basis. The generation of all other frames is event controlled (with additional time monitoring per node).

The MN starts the isochronous data exchange after the SoC frame has been sent. A PReq frame is sent to every configured and active node. The accessed node responds by a PRes frame.

Both the PReq and the PRes frames shall transfer application data. The MN shall only send PReq data to one CN per frame. PReq transfer is dedicated to data relevant for the addressed CN only. In contrast, the PRes frame is received by all nodes. This makes communication relationships possible according to the producer/consumer model.

The PReq / PRes procedure is repeated for each configured and active isochronous CN. The MN may send a multicast PRes frame to all nodes. This frame is dedicated to transfer data relevant for groups of CNs. The order in which CNs are polled and the PRes frame of the MN is sent, is beyond the scope of this standard.

The isochronous phase is calculated from start of the SoC frame to start of the SoA frame.

The size and the length of the Type 13 fieldbus cycle is predominantly affected by the size of the isochronous phase. When configuring the Type 13 fieldbus cycle, the sum of the times required by the PReq / PRes accesses to each configured CN shall be taken into account. Use of the multiplexed or continuous-time-triggered access technology reduces the amount of time.

Continuous, continuous-time-triggered and multiplexed access operates in parallel during one Type 13 fieldbus cycle. The apportionment of the isochronous phase to continuous, continuous-time-triggered and multiplexed slots is configuration specific and not scope of this standard.

Although the multiplexed nodes are not processed in each cycle, they can monitor the entire data transfer of the continuous nodes.

In case of MN cycle loss, the multiplexed access sequence is continued on a per time base, after the cycle loss error phase is over.

4.2.2.2 Asynchronous phase

In the asynchronous phase of the Type 13 fieldbus cycle, access to the network is permitted to be granted to one CN or to the MN for the transfer of a single asynchronous message only.

There are two types of asynchronous frames available:

- the ASnd frame (Async Send);
- a Legacy Ethernet message.

In the SoA frame the MN assigns the permission to send an asynchronous frame to a CN or to itself. If no asynchronous message transmission request is pending at the MN scheduling queues, the MN shall issue a SoA without assignment of the right to send to any node. No ASnd frame and no legacy Ethernet message will follow the SoA frame in this case.

The SoA frame is the first frame in the asynchronous phase and is a signal to all CNs that all isochronous data have been exchanged during the isochronous phase.

In case of a Type 13 fieldbus ASnd frame, the user data may contain following data, depending upon MN request and application.

- Ident Data: The identification data of a CN.
- Status Data: The current status and detailed error information of a node.
- Sync Data: The synchronization data of a continuous-time-triggered CN.
- NMT Data: A NMTCommand from the MN to one or more CNs or a NMTRRequest from a CN to the MN.
- Unspecified Data: Unspecified data communication may be used to transfer peer to peer communication with access to the object dictionary of a device, IP-based protocols like TCP or UDP and higher layer protocols such as HTTP, FTP, ...

In case of a legacy Ethernet message, the data could contain any legal Ethernet frame. The message is forwarded to the application without any further interpretation.

The asynchronous phase is calculated from the start of SoA to the end of the asynchronous response.

4.2.2.3 Idle phase

The idle phase is the remaining time interval between the end of the asynchronous phase and the beginning of the next cycle. During the idle Phase, all network components are “waiting” for the beginning of the following cycle. The duration of the idle phase may be 0.

4.3 Service assumed from the PhL

Subclause 4.3 describes the assumed physical service (PhS) and the constraints used by the DLE. The Physical Service is assumed to provide the following service primitives specified by ISO/IEC 8802-3:2000, Clause 2.

The assumed primitives of PhS are

- MA_DATA.request
- MA_DATA.indication

The temporal relationship of the primitives is shown in Figure 4.

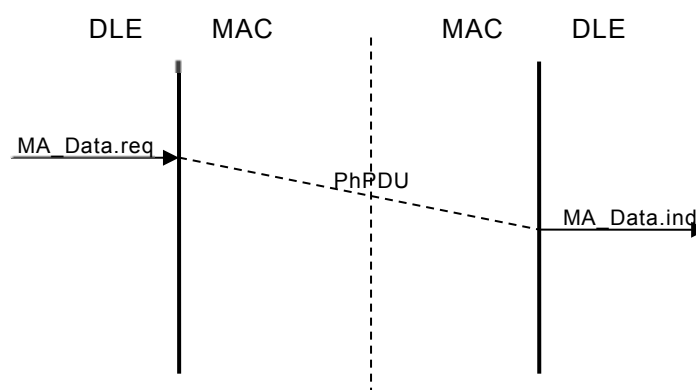


Figure 4 – Interaction of PhS primitives to DLE

The MA_DATA request primitive defines the transfer of data from a MAC client entity to a single peer entity or multiple peer entities in the case of group addresses.

The MA_DATA indication primitive defines the transfer of data from the MAC sublayer entity (through the optional MAC control sublayer, if implemented) to the MAC client entity or entities in the case of group addresses.

4.4 DLL architecture

The Type 13 fieldbus DLL is modeled as a combination of control components of cycle state machine (CSM), isochronous transmission TX/RX control (ITC), asynchronous transmission TX/RX control (ATC), asynchronous slot scheduler (ASS), exception signaling (ES), NMT signaling (NS) and DLL management interface.

The cycle state machine as the primary control component provides the function for deterministic medium access control cooperating for reliable and efficient support of higher-level data transfer services. According responsibility assignment for MN and CN the primary responsibility for CN is

- to handle communication within a Type 13 fieldbus cycle;
- to track the order of the frames received within a cycle and reacts according to the described dataflow;
- to generate an error event in case of a detected communication error;
- to hold up communication regardless to any errors.

The cycle state machine of the MN is responsible for:

- Managing the communication within a Type 13 fieldbus cycle.
- Generating the flow of the frames during a Type 13 fieldbus cycle.
- Monitoring the reaction of the CNs.
- Generating an error event in case of a detected communication error.

The data-link layer is comprised of the components listed in Table 1.

Table 1 – Data-link layer components

Components	Description
Cycle state machine (CSM)	The cycle state machine controls the Type 13 fieldbus cycle on the data-link layer, assembles and transmits the DLPDUs, receives and disassembles the DLPDUs with the control information, and determines the timing and duration of the transmissions
Isochronous transmission TX/RX control (ITC)	The ITC buffers and dispatches in time DLSDU received for the time-critical cyclic data transfer between the DLS-user and the SCM
Asynchronous transmission TX/RX control (ATC)	The ATC queues and dispatches in time DLSDU received for the asynchronous data transfer between DLS-user and the SCM
Asynchronous Slot Scheduler (ASS)	The MNs asynchronous slot scheduler decides when a requested asynchronous data transfer will happen
Exception Signaling (ES)	The exception signaling signals a detected CN exception to the MN NMT
NMT Signaling (NS)	The NS reports the current status of the NMT
DLL management interface	The DLL management interface holds the station management variables that belong to the DLL, and manages synchronized changes of the link parameters

The internal arrangement of these components, and their interfaces, are shown in Figure 5. The arrowheads illustrate the primary direction of the flow of data and control.

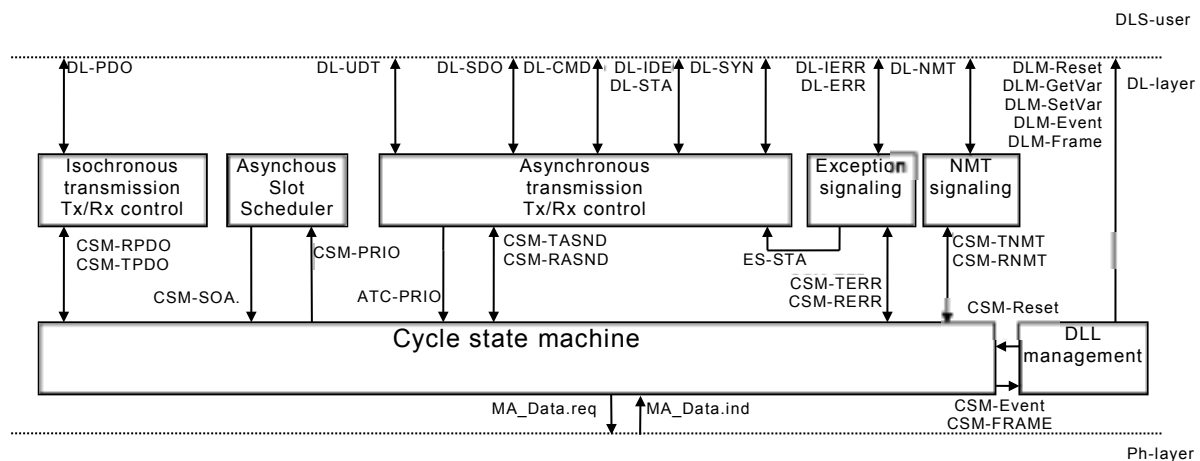


Figure 5 – Data-link layer internal architecture

4.5 Local parameters and variables

This specification uses DLS-user request parameters $P(\dots)$ and local variables $V(\dots)$ as a means of clarifying the effect of certain actions and the conditions under which those actions are valid, local timers $T(\dots)$ as a means of monitoring actions of the distributed DLS-provider and of ensuring a local DLE response to the absence of those actions, and local counters $C(\dots)$ for performing rate measurement functions.

Unless otherwise specified, at the moment of their creation or of DLE activation:

- all variables shall be initialized to their default value, or to their minimum permitted value if no default is specified;
- all counters shall be initialized to zero;
- all timers shall be initialized to inactive;

DL-management may change the values of configuration variables.

4.5.1 Variables, parameter, counter and timer to support DLE function

4.5.1.1 $T(\text{ASND_TIME})$

$T(\text{ASND_TIME})$ is used by the DLE to measure the time elapsed since last sending a SoA frame. The value is decremented in the range of $V(\text{AsyncSlotTimeout_U32})$ to 0.

4.5.1.2 $V(\text{AsyncSlotTimeout_U32})$

This variable holds and designates the value of the timeout time for the ASnd frame in ns. An event is produced when the ASnd frame was not (or not completely) received within a preconfigured time. The initial value is 100 000 on power-up or reset of this node. The range of this value starts at 250.

4.5.1.3 $P(\text{C_DLL_ISOCHR_MAX_PAYL})$

This parameter indicates the maximum size of PReq and PRes payload data in octets. The value is set to 1 490.

4.5.1.4 $P(\text{C_DLL_MAX_PAYL_OFFSET})$

This parameter indicates the maximum offset of Ethernet frame payload in octets. The value is set to 1 499.

4.5.1.5 P(D_DLL_CNFeatureMultiplex_BOOL)

This parameter indicates the CN ability to perform control of multiplexed isochronous communication.

4.5.1.6 P(D_DLL_FeaturePResTimeTriggered_BOOL)

This parameter indicates the node ability to perform control of continuous-time-triggered isochronous communication.

4.5.1.7 P(D_DLL_MNFeatureMultiplex_Bool)

This parameter indicates the MNs ability to perform control of multiplexed isochronous communication.

4.5.1.8 P(D_NMT_CycleTimeMax_U32)

This parameter holds the maximum Type 13 fieldbus cycle time in μs .

4.5.1.9 P(D_NMT_CycleTimeMin_U32)

This parameter holds the minimum Type 13 fieldbus cycle time in μs .

4.5.1.10 P(D_NMT_NetTime_BOOL)

This parameter indicates the MNs ability to support of NetTime transmission via SoC DLPDU.

4.5.1.11 P(D_NMT_NetTimeIsRealTime_BOOL)

This parameter indicates the MNs ability to support of real time via the NetTime parameter in SoC DLPDU.

4.5.1.12 P(D_NMT_RelativeTime_BOOL)

This parameter indicates the MNs ability to support of RelativeTime transmission via SoC DLPDU.

4.5.1.13 T(FRAME_TIME)

T(FRAME_TIME) is used by the DLE to measure the time elapsed since last receiving a SoC, SoA and PReq frame. The value is decremented in the range of V(FRAME_TIMEOUT) to 0.

4.5.1.14 V(FRAME_TIMEOUT)

This variable holds and designates the value of the timeout time for the SoC, SoA and PReq frame. An event is produced when one of the frames were not (or not completely) received within a preconfigured time. This event signifies that a mandatory frame of the MN was lost.

4.5.1.15 V(MultiplCycleCnt_U8)

This variable describes the length of the multiplexed cycle in multiples of the Type 13 fieldbus cycle. The variable should be set by the system configuration and should be equal in all nodes of the segment. If this variable is zero, there is no support of multiplexed cycle on the network.

4.5.1.16 V(NMT_CycleLen_U32)

This variable defines the communication cycle time interval (synchronization interval) in μs . The variable should be set by the system configuration in the range of P(D_NMT_CycleTimeMin_U32) to P(D_NMT_CycleTimeMax_U32).

4.5.1.17 V(NMT_Version_U8)

The variable holds the Type 13 fieldbus communication profile version that is implemented by the device. The value shall be set by the device during system initialization.

4.5.1.18 V(NMT_IsochrSlotAssign_AU8)

This variable assigns CNs to a particular isochronous slot. The variable should be set by the system configuration in the range of 0 to 254.

4.5.1.19 V(NMT_MultiplCycleAssign_AU8)

This variable assigns CNs to the particular Type 13 fieldbus cycles of the multiplexed cycle period defined by V(MultiplCycleCnt_U8). It shall be equal in all nodes of the segment. The variable should be set by the system configuration in the range of 0 to V(MultiplCycleCnt_U8).

4.5.1.20 V(NodeID_U8)

The variable holds the device's actual Node ID. V(NodeID_U8) may be provided by hardware settings (dip switch etc.) or set up by software in the range of 1 to 240, 253 and 254.

4.5.1.21 T(PRES_TIME)

T(PRES_TIME) is used by the DLE to measure the time elapsed since last sending a PReq frame. The value is decremented in the range of V(PRES_TIMEOUT) to 0.

4.5.1.22 T(PRES_TT_TIME)

T(PRES_TT_TIME) is used by the DLE of a CN to measure the time elapsed since last receiving a PRes frame from the MN. The value is decremented in the range of V(PRES_TT_TIMEOUT) to 0.

4.5.1.23 V(PRES_TIMEOUT)

This variable holds and designates the value of the timeout time for the PRes frame in μs . An event is produced when the PRes frame was not (or not completely) received within a preconfigured time.

4.5.1.24 V(PRES_TT_TIMEOUT)

This variable holds and designates the value of the timeout time in μs for a continuous-time-triggered CN when to send its PRes frame.

4.5.1.25 V(Prescaler_U16)

This variable describes the toggle rate of the PS flag within the SoC DLPDU. The value provides the number of Type 13 fieldbus cycles that have to be completed to toggle the flag by the MN. The initial value is 2 on power-up or reset of this node. The range of this value is 0 to 1 000.

If this variable is 0, there shall be no toggling of the PS flag. V(Prescaler_U16) shall be equal in all nodes of the segment.

5 General structure and encoding of PhPDUs and DLPDU and related elements of procedure

5.1 Overview

The DLL and its procedures are necessary to provide the services offered to the DLS user by using the services available from the PhL. Clause 5 describes the structure and semantics of MA_PDU, DLPDU and the procedure, commonly used in this specification. Nevertheless this portion is identical to and fully compliant with ISO/IEC 8802-3.

NOTE Within Clause 5, any reference to bit k of an octet is a reference to the bit whose weight in a one-octet unsigned is 2^k , and this is sometimes referred to as "little endian" bit numbering.

5.2 MA_PDU structure and encoding

The local MAC sublayer uses the service primitives provided by the PhS sublayer specified by ISO/IEC 8802-3 Clause 2. All of the service primitives provided by the PhS sublayer are as follows and are considered mandatory:

- a) MA_DATA request;
- b) MA_DATA indication;

5.3 Common MAC frame structure, encoding and elements of procedure

5.3.1 MAC frame structure

5.3.1.1 MAC frame format for the Type 13 fieldbus DLPDU

The DLPDU for the Type 13 fieldbus is encapsulated in the data field of a MAC frame as specified by ISO/IEC 8802-3, Clause 3. The value of the Length/Type field is designated to 88AB_H, which is authorized and registered as the protocol identification number by the IEEE Registration Authority, to be identified as the Type 13 fieldbus frame. Figure 6 shows the Type 13 fieldbus DLPDU.

Message type	1 OCTET
Destination	1 OCTET
Source	1 OCTET
Data	

Figure 6 – Type 13 fieldbus DLPDU

The length of the frame shall be restricted to the configured size. Otherwise the cycle time cannot be guaranteed. Ethernet frames shall not be shorter than the specified minimum of 64 octets.

5.3.1.2 MAC frame format non-Type 13 fieldbus DLPDU

Any MAC frame as specified by ISO/IEC 8802-3, Clause 3 applies, with the exception of MAC frames with Length/Type field designated to 88AB_H.

5.3.2 Elements of the MAC frame

5.3.2.1 General

This subclause specifies the Type 13 fieldbus usage of ISO/IEC 8802-3 MAC frame elements.

5.3.2.2 Destination address field (DA)

The destination address (DA) field is specified in ISO/IEC 8802-3:2000, Clause 3. The destination address field specifies the station(s) for which the frame is intended. It may be an individual or multicast (including broadcast) address.

In case of Type 13 fieldbus DLPDU Table 2 shows the MAC multicast addresses, when destination is set to “Type 13 fieldbus broadcast” (see 5.3.3.2). Otherwise the DA is set to the corresponding node ID, resolved by the application layer.

Table 2 – MAC multicast addresses

Frame type	ID / Abbr.	MAC-multicast address
Start of cycle (SoC)	SoC	01-11-1E-00-00-01 (C_DLL_MULTICAST_SOC)
PollResponse (PRes)	PRes	01-11-1E-00-00-02 (C_DLL_MULTICAST_PRES)
Start of Asynchronous (SoA)	SoA	01-11-1E-00-00-03 (C_DLL_MULTICAST_SOA)
AsynchronousSend (ASnd)	ASnd	01-11-1E-00-00-04 (C_DLL_MULTICAST_ASND)

5.3.2.3 Source address field (SA)

The source address (SA) field is specified in ISO/IEC 8802-3:2000, Clause 3. The source address field specifies the station sending the frame.

5.3.2.4 Length/type field

The Length/type field is specified in ISO/IEC 8802-3:2000, Clause 3. In order to be identified as Type 13 fieldbus frame, the value of the length/type field is set to 88AB_H, which is authorized and registered as protocol identification number for Type 13 fieldbus by the IEEE registration authority. Every frame with the value not equal to 88AB_H is processed as a legacy Ethernet frame inside an asynchronous slot.

5.3.3 Elements of the Type 13 fieldbus DLPDU

This subclause specifies the elements of a Type 13 fieldbus DLPDU as depicted in Figure 6.

5.3.3.1 Message type

The message type field is used by the DLE to identify and designate the frame type of the Type 13 fieldbus for medium access control. Table 3 shows the list of message types for Type 13 fieldbus.

Table 3 – Message types

Message Type	Value	ID / Abbr.
Start of Cycle	01h	SoC
PollRequest	03h	PReq
PollResponse	04h	PRes
Start of Asynchronous	05h	SoA
Asynchronous Send	06h	ASnd

5.3.3.2 Destination

Node ID of the addressed node(s). The destination address field specifies the station(s) for which the frame is intended. It may be an individual or a broadcast address.

Table 4 shows the list of node ID for destination address(es).

Table 4 – Node ID assignment

Node ID	Description
0	Invalid
1..239	Regular Type 13 fieldbus CNs
240	Type 13 fieldbus MN
241..250	Reserved
251	Pseudo node ID to be used by a node to address itself
252	Dummy node ID
253	Type 13 CN (Diagnostic device)
254	Type 13 CN (Routing device)
255	Type 13 fieldbus broadcast

5.3.3.3 Source

Node ID of the transmitting node. The source address field specifies the station sending the frame. In case of a transmitted multicast / broadcast message, the source address is interpreted by the DLE. The value of the source address is always set to V(NodeID_U8).

Table 4 shows the list of node IDs for the source address. The node IDs 251, 252 and 255 (broadcast) shall not be used as a source address.

5.3.3.4 Data

The data field contains a sequence of N octets which provides full data transparency in the sense that any arbitrary sequence of octet values may appear in the data field up to a maximum number specified by ISO/IEC 8802-3. A minimum frame size is required, that is minFrameSize by ISO/IEC 8802-3, and if a frame size is less than minFrameSize, then the data field is extended by appending extra bits in units of octets.

The structure of this field for the Type 13 fieldbus DLPDU is described in Clause 6.

5.4 Invalid DLPDU

An invalid DLPDU shall be defined as one that meets at least one of the following conditions.

- The frame length is inconsistent with a length value specified in the Length/Type field. If the Length/Type field contains a type value as defined by ISO/IEC 8802-3:2000, subclause 3.2.6, then the frame length is assumed consistent with this field and should not be considered an invalid DLPDU on this basis.
- It is not an integral number of octets in length.
- The bits of the incoming DLPDU (exclusive of the FCS field itself) do not generate a CRC value identical to the one received.
- It is inconsistent with a Message Type value of Type 13 fieldbus DLPDU.

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

NOTE Invalid DLPDU may be ignored, discarded, or used in a private manner by DLS-users. The use of such DLPDUs is beyond the scope of this specification.

6 DLPDU-specific structure, encoding and elements of procedure

6.1 General

Clause 6 defines the structure, contents and encoding of each type and format of the DLPDU, and specifies elements of procedure for the DLPDU.

Within each subclause, the structure, contents, parameters and encoding of the DLPDU are described, and the Type 13 fieldbus specific part of the DLPDU structure, which is shown in Figure 6, is specified. The aspects relating to the sending and receiving of DLS-users and their DLEs are further described. All data format and encoding is described in little endian format throughout Clause 6.

NOTE Within Clause 6, any reference to bit k of an octet is a reference to the bit whose weight in a one-octet unsigned is 2^k , and this is sometimes referred to as "little endian" bit numbering.

6.2 Overview

Type 13 fieldbus collects more than one function into one frame. It is therefore not usually possible to apply a single communication relationship to the complete frame, but only to particular services inside the frame.

The PRes DLPDU for example transmitted by the CN includes several services.

- Transmission of the current NMT status of the CN is the response part of an unconfirmed master/slave relationship triggered by the MN.
- Request of the asynchronous slot is the request part of a client/server relationship.
- Transmission of PDO data occurs in conformance to a push model producer/consumer relationship.

6.3 Start of synchronization (SoC)

6.3.1 General

The SoC DLPDU is used for synchronisation of all nodes. Only the MN shall initiate the SoC DLPDU.

At the beginning of a Type 13 fieldbus cycle, the MN shall send a SoC DLPDU to all nodes. The sending and receiving time of this frame is the basis for the common timing of all the nodes. Only the SoC DLPDU is generated on a periodic basis. The generation of all other frames shall be event controlled (with additional time monitoring per node).

The MN starts the isochronous data exchange after the SoC frame has been sent.

6.3.2 Structure of the SoC DLPDU

The structure of SoC DLPDU is shown in Table 5.

Table 5 – Structure of SoC DLPDU

DLPDU field	Data type	Value/description
Message type	OCTET[1]	01h / Identify the SoC DLPDU
Destination	OCTET[1]	Node ID of the addressed node
Source	OCTET[1]	Node ID of the transmitting node
reserved	OCTET[1]	
SOC-flag	OCTET[1]	
reserved	OCTET[1]	
NetTime	OCTET[8]	Starting time of the Type 13 fieldbus cycle
RelativeTime	OCTET[8]	Relative time
reserved	OCTET[24]	

6.3.2.1 Parameters of SoC DLPDU

6.3.2.1.1 Destination (dest)

This parameter indicates the Node ID of the addressed node (see 5.3.3.2). For SoC DLPDU the destination is set to 255 (C_ADDR_BROADCAST).

6.3.2.1.2 Source (src)

This parameter indicates the Node ID of the transmitting node (see 5.3.3.3). For SoC DLPDU, the parameter is set to 240 (C_ADDR_MN_DEF_NODE_ID).

6.3.2.1.3 SOC-Flag

6.3.2.1.3.1 General

The structure of the SoC-Flag is shown in Table 6.

Table 6 – Structure of SoC-Flag

Bit number	Value	Description
7		Multiplexed cycle complete (MC)
6		Prescaled slot (PS)
5-0		Reserved

6.3.2.1.3.2 Multiplexed cycle complete (MC)

This parameter is toggled by the MN when the final multiplexed cycle has ended. The parameter is generated within the ITC and signaled to the application within the DLMS frame status.

6.3.2.1.3.3 Prescaled slot (PS)

This parameter is toggled by the MN every n-th cycle (n is configurable by V(Prescaler_U16))

The parameter is signaled to the application within the DLMS frame status.

NOTE This prescaled signal is useful for “slow” nodes, which cannot react every cycle.

6.3.2.1.4 NetTime (time)

This parameter is distributed by the MN and indicates the starting time of the Type 13 fieldbus cycle.

NetTime transmission is optional. Support is indicated by P(D_NMT_NetTime_BOOL).

IEC 61588 conform distribution via the parameter NetTime is indicated by P(D_NMT_NetTimelsRealTime_BOOL).

6.3.2.1.5 RelativeTime (reltime)

This parameter is distributed by the MN and indicates the relative time, which is incremented by the Type 13 fieldbus cycle time when a SoC DLPDU is generated. The unit of RelativeTime is μs .

RelativeTime transmission is optional. Support is indicated by P(D_NMT_RelativeTime_BOOL).

6.3.2.2 User data

No user data is conveyed by the SoC DLPDU.

6.3.3 Sending SoC DLPDU

The CSM of the MN sends out the SoC DLPDU with a set of parameters, as stated above. The time interval of the periodic basis is determined by V(NMT_CycleLen_U32).

6.3.4 Receiving the SoC DLPDU

Each node receives this DLPDU to synchronize his behavior on this DLPDU. The CSM of the CNs use this DLPDU for:

- Indicating the beginning of a Type 13 fieldbus cycle.
- Exception recognition.
- Cycle time overrun.

The reception and the parameter of this DLPDU is signaled by the DLMS frame status for synchronization purpose.

The MN shall observe network traffic in order to ensure, that there is no other MN active on the network. Reception of a SoC or a SoA DLPDU indicates that there is another MN active.

6.4 PollRequest (PReq)

6.4.1 General

The real-time data transfer is performed by means of process data objects (PDO). PDO communication in Type 13 fieldbus is always performed isochronously by PReq and PRes DLPDUs.

The MN only sends PReq DLPDU to one CN per frame. PReq transfer is dedicated to data relevant for the addressed CN only. The addressed CN response its process data object to all nodes. This makes communication relationships possible according to the producer/consumer model. The PReq / PRes procedure shall be repeated for each configured and active isochronous CN during each cycle. The MN may send an PRes DLPDU to all CN.

A further assignment of the PReq DLPDU is the exception signaling. A flag inside the DLPDU is used to acknowledge an exception signal received by a particular CN to the particular CN.

6.4.2 Structure of the PReq DLPDU

6.4.2.1 General

The structure of PReq DLPDU is shown in Table 7.

Table 7 – Structure of PReq DLPDU

DLPDU field	Data type	Value/description
Message type	OCTET[1]	03h / identify the PReq DLPDU
Destination	OCTET[1]	Node ID of the addressed node
Source	OCTET[1]	Node ID of the transmitting node
reserved	OCTET[1]	
PReq-flag	OCTET[1]	
reserved	OCTET[1]	
Payload	OCTET[4 to P(C_DLL_MAX_PAYL_OFFSET)-10]	DLSDU

6.4.2.2 Parameters of PReq DLPDU

6.4.2.2.1 Destination (dest)

This parameter indicates the Node ID of the addressed node (see 5.3.3.2). For PReq DLPDU only individual CN Node IDs are allowed.

This parameter is inserted/evaluated to/from the DLS-User as the D_addr parameter within the DLS DL-PDO.

6.4.2.2.2 Source (src)

This parameter indicates the node ID of the transmitting node (see 5.3.3.3). For PReq DLPDU, the parameter is set to 240 (C_ADDR_MN_DEF_NODE_ID).

This parameter is passed to the DLS-User as the S_addr parameter within the DLS DL-PDO.

6.4.2.2.3 PReq-Flag

6.4.2.2.3.1 General

The structure of PReq-Flag is shown in Table 8.

Table 8 – Structure of PReq-Flag

Bit number	Value	Description
7-6		Reserved
5		Multiplexed slot (MS)
	0	Isochronous slot is handled in a non-multiplexed slot
	1	Isochronous slot is handled in a multiplexed slot
4-3		Reserved
2		Exception acknowledge (EA)
1		Reserved
0		Ready (RD)
	0	DLSDU is not valid
	1	DLSDU is valid

6.4.2.2.3.2 Multiplexed slot (MS)

This parameter is set by the MN when the addressed CN is handled in a multiplexed timeslot. The parameter is generated within the ITC and signaled to the application within DLS DL-PDO.

6.4.2.2.3.3 Exception acknowledge (EA)

This parameter is toggled by the MN to acknowledge a requested exception signal from the addressed CN. The parameter is generated / evaluated within the ES.

For async-only CNs, the parameter is also signaled within the DLSDU of DL-STA. The CSM is responsible to insert/remove this parameter into the DL-STA.

6.4.2.2.3.4 Ready (RD)

This parameter indicates that the transferred payload data are valid. The parameter is passed/received to/from the DLS-User within the DLS DL-PDO primitive.

6.4.2.2.4 Payload (pl)

PReq DLPDU can transmit user data up to the length of P(C_DLL_ISOCHR_MAX_PAYL). The parameter is passed/received to/from the DLS-User within the DLS DL-PDO primitive.

6.4.3 Sending PReq DLPDU

A PReq DLPDU shall be sent to every configured and active node every Type 13 fieldbus cycle under consideration of the multiplexed slot. A PReq DLPDU shall not be sent to a CN configured as a continuous-time-triggered node.

The CSM of the MN administrates access to all CNs via PReq DLPDU during a multiplexed cycle. For each slot, the MNs CSM requests the transmitting DLSDU via ITC and assembles them to the PReq DLPDU including the exception signaling information.

The MN uses a timeout after sending a PReq DLPDU for receiving the corresponding PRes DLPDU response to detect transmission errors and node failures.

6.4.4 Receiving the PReq DLPDU

Each isochronous continuous or multiplexed CN shall receive a PReq DLPDU from the MN in the Type 13 fieldbus cycle and shall send a PRes DLPDU to the MN. CNs may be accessed every cycle or every n^{th} cycle (multiplexed nodes, $n > 1$).

The received data is unpacked and passed directly to the ITC via CSM-RPDO. The exception acknowledge parameter is passed to the ES via CSM-ERR for further processing.

6.5 Poll response (PRes)

6.5.1 General

Each isochronous continuous or multiplexed CN shall receive an unicast PReq DLPDU from the MN in the Type 13 fieldbus cycle and shall response with a PRes DLPDU to the MN. Each isochronous continuous-time-triggered CN shall receive the PRes DLPDU from the MN in the Type 13 fieldbus cycle and shall send a PRes DLPDU to the MN on a time triggered basis. PReq and PRes DLPDU may transport isochronous data.

PReq can only be received by the specifically addressed CN. However, PRes DLPDU shall be sent by the CN as multicast messages, allowing all other CNs to monitor the data being sent.

Additional data from the MN may be received by a multicast PRes DLPDU transmitted by the MN.

CNs participating in the isochronous slot shall request the right to transmit asynchronous data from the MN via the PR / PS parameter of the PRes DLPDU.

New exception conditions and the current NMT status of the CN is also transmitted within the PRes DLPDU.

6.5.2 Structure of the PRes DLPDU

6.5.2.1 General

The structure of PRes DLPDU is shown in Table 9.

Table 9 – Structure of PRes DLPDU

DLPDU field	Data type	Value/description
Message type	OCTET[1]	04h / identify the PRes DLPDU
Destination	OCTET[1]	Node ID of the addressed node
Source	OCTET[1]	Node ID of the transmitting node
NMTStatus	OCTET[1]	Status of the CNs NMT state machine
PRes-flag	OCTET[2]	
Payload	OCTET[4 to P(C_DLL_MAX_PAYL_OFFSET)-10]	DLSDU

6.5.2.2 Parameters of PRes DLPDU

6.5.2.2.1 Destination (dest)

This parameter indicates the node ID of the addressed node (see 5.3.3.2). For PRes DLPDU the destination is set to 255 (C_ADDR_BROADCAST).

This parameter is inserted/evaluated to/from the DLS-User as the D_addr parameter within the DLS DL-PDO.

6.5.2.2.2 Source (src)

This parameter indicates the node ID of the transmitting node (see 5.3.3.3).

This parameter is passed to the DLS-User as the S_addr parameter within the DLS DL-PDO.

6.5.2.2.3 NMTStatus (stat)

This parameter reports the current status of the CNs NMT state machine and is inserted/evaluated to/from the DLS-User with DLS DL-NMT.

6.5.2.2.4 PRes-Flag

6.5.2.2.4.1 General

The structure of PRes-Flag is shown in Table 10.

Table 10 – Structure of PRes-Flag

Bit number	Value	Description
15-14		Reserved
13		Multiplexed slot (MS)
	0	Isochronous slot is handled in a non-multiplexed slot
	1	Isochronous slot is handled in a multiplexed slot
12		EN
11-9		Reserved
8		Ready (RD)
	0	DLSDU is not valid
	1	DLSDU is valid
7-6		Reserved
5-3		Priority (PR)
	000	PRIO_0
	001	PRIO_1
	010	PRIO_2
	011	PRIO_GENERIC_REQUEST
	100	PRIO_4
	101	PRIO_5
	110	PRIO_6
	111	PRIO_NMT_REQUEST
2-0		RequestToSend (RS)
	000	no pending request
	001	1 pending request
	010	2 pending requests
	011	3 pending requests
	100	4 pending requests
	101	5 pending requests
	110	5 pending requests
	111	7 and more pending requests

6.5.2.2.4.2 Multiplexed slot (MS)

This parameter is done by the corresponding PReq DLPDU when the addressed CN is handled in a multiplexed timeslot. The parameter is signaled to the application within the DLS DL-PDO primitive.

Based on this information, other CNs can identify that the transmitting CN is served by a multiplexed slot.

6.5.2.2.4.3 Exception new (EN)

This parameter is toggled by the CN to indicate an exception signal to the MN. The parameter is generated / evaluated within ES.

For async-only CNs, the parameter is also signaled within the DLSDU of DL-STA. The CSM is responsible to insert/remove this parameter into the DL-STA.

6.5.2.2.4.4 Ready (RD)

This parameter indicates that the transferred payload data are valid. The parameter is passed/received to/from the DLS-User within the DLS DL-PDO primitive.

6.5.2.2.4.5 Priority (PR)

This parameter indicates the priority of the frame(s) in the asynchronous send queue with the highest priority. The range of this value is 0 (lowest priority) to 7 (highest priority). Two of these levels are dedicated to Type 13 fieldbus purpose:

- PRIO_NMT_REQUEST: This is the highest priority that shall be exclusively applied if a CN requests an NMT command to be issued by the MN.
- PRIO_GENERIC_REQUEST: Medium priority which is the standard priority level for non-NMT command requests.

The remaining priority levels above and below PRIO_GENERIC_REQUEST are available for application purpose.

Before transmitting the PRes DLPDU, ATC is requested for the current status of the asynchronous send queues.

6.5.2.2.4.6 RequestToSend (RS)

This parameter indicates the number of pending frames in the asynchronous send queue with the highest priority. The range of this value is 0 (no pending request) to 7 (7 and more pending requests).

Before transmitting the PRes DLPDU, ATC is requested for the current status of the asynchronous send queues.

6.5.2.2.5 Payload (pl)

PRes DLPDU can transmit user data up to the length of P(C_DLL_ISOCHR_MAX_PAYL). The parameter is passed/received to/from the DLS-User within the DLS DL-PDO primitive.

6.5.3 Sending PRes DLPDU

A PRes DLPDU shall be sent as the response to a received PReq DLPDU in case of a continuous or multiplexed CN, as the response to a received PRes DLPDU from the MN in case of a continuous-time-triggered CN on a time triggered basis or by the MN.

The DLPDU is assembled by requesting the ITC for the DLSDU transmitting to all nodes, requesting the ATC for the current status of the asynchronous sending queues, requesting the ES for the actual exception new parameter and requesting the NS for the actual CNs NMTStatus.

6.5.4 Receiving the PRes DLPDU

The PRes DLPDU is received by all isochronous CNs as well as the MN.

The received data is unpacked and passed directly to the ITC via the CSM-RPDO service. The EA parameter is passed to the ES via CSM-ERR and the NMTStatus is passed to the NS for further processing.

The MN uses a timeout after sending a PReq DLPDU resp. after sending its PRes DLPDU in case of continuous-time-triggered nodes for receiving the corresponding PRes DLPDU response to detect transmission errors and node failures.

6.6 Start of asynchronous (SoA)

6.6.1 General

The SoA DLPDU shall be used to

- identify CNs,
- request status information of a CN,
- send NMT commands,
- poll async-only CNs and
- grant the asynchronous transmit right to one CN,
- synchronize continuous-time-triggered CNs.

The SoA DLPDU is the first frame in the asynchronous phase and is a signal to all CNs that all isochronous data have been exchanged during the isochronous phase. If no asynchronous message transmission request is pending the SoA DLPDU without assignment of the right to send any message is transmitted.

The SoA DLPDU is handled by the MN. The MN knows its own asynchronous send queue and the queues of all active CNs, reported via PRes DLPDU. The ASS of the MN shall determine in which cycle the right to send the asynchronous frame will be granted. It shall guarantee that no send request will be delayed for an indefinite amount of time, even if network load is high.

Assignment of the asynchronous slot to the MN itself shall be indicated in the same way as assignments to CNs.

6.6.2 Structure of the SoA DLPDU

6.6.2.1 General

The structure of SoA DLPDU is shown in Table 11.

Table 11 – Structure of SoA DLPDU

DLPDU field	Data type	Value/description
Message Type	OCTET[1]	05h / identify the SoA DLPDU
Destination	OCTET[1]	Node ID of the addressed node
Source	OCTET[1]	Node ID of the transmitting node
NMTStatus	OCTET[1]	Status of the MNs NMT state machine
SoA-Flag	OCTET[1]	
reserved	OCTET[1]	
svid	OCTET[1]	Requested serviceID (svid)
svtg	OCTET[1]	Requested service target (svtg)
FieldbusVersion	OCTET[1]	Type 13 fieldbus version of the MN
reserved	OCTET[1]	
Payload	OCTET[36]	DLSDU

6.6.2.2 Parameters of SoA DLPDU

6.6.2.2.1 Destination (dest)

This parameter indicates the node ID of the addressed node (see 5.3.3.2). For SoA DLPDU the destination is set to 255 (C_ADDR_BROADCAST).

NOTE The target of this DLPDU is indicated within the RequestedServiceTarget parameter (see 6.6.2.2.6). Destination set to 255 (C_ADDR_BROADCAST) is necessary for synchronization purpose of the CSM.

6.6.2.2.2 Source (src)

This parameter indicates the Node ID of the transmitting node (see 15.4.8). For SoA DLPDU, the parameter is set to 240 (C_ADDR_MN_DEF_NODE_ID).

6.6.2.2.3 NMTStatus (stat)

This parameter reports the current status of the MNs NMT state machine and is inserted/evaluated to/from the DLS-User with the DLS DL-NMT.

6.6.2.2.4 SoA-Flag

6.6.2.2.4.1 General

The structure of SoA-Flag is shown in Table 12.

Table 12 – Structure of SoA-Flag

Bit number	Value	Description
7-3		Reserved
2		Exception acknowledge (EA)
1		Exception reset (ER)
	0	No request
	1	Request initialization of the exception system
0		Reserved

6.6.2.2.4.2 Exception acknowledge (EA)

This parameter is toggled by the MN to acknowledge a requested exception signal from the addressed CN. The parameter is generated / evaluated within the ES. The parameter is valid only, if RequestedServiceID equals StatusRequest.

For isochronous CNs, the parameter is also signaled within the PReq DLPDU. The CSM is responsible to insert/remove this parameter into the DL-STA.

6.6.2.2.4.3 Exception reset (ER)

This parameter is set by the MN to reset the internal exception flag from the addressed CN. The parameter is generated / evaluated within the ES. The parameter is valid only, if RequestedServiceID equals StatusRequest.

6.6.2.2.5 RequestedServiceID (svid)

This parameter indicates the asynchronous service ID dedicated to the following asynchronous slot.

Table 13 shows the definitions of the RequestServiceID entries.

Table 13 – Definition of the RequestedServiceID in the SoA DLPDU

Description	Value (ID)	Description
NoService	00 _h NO_SERVICE	Shall be used if the asynchronous slot is not assigned to any node. RequestedServiceTarget shall be C_ADDR_INVALID
IdentRequest	01 _h IDENT_REQUEST	Shall be used to identify inactive CNs and/or to query the identification data of a CN. The addressed CN shall answer immediately after the reception of the SoA with the node specific IdentResponse ASnd DLPDU
StatusRequest	02 _h STATUS_REQUEST	Shall be used to request the current status and detailed error information of a node. Async-only CNs shall be cyclically queried by StatusRequest to supervise their status and to query their requests for the asynchronous slot. The addressed node shall answer immediately after the reception of the SoA, with the node specific StatusResponse ASnd DLPDU frame
NMTRequestInvite	03 _h NMT_REQUEST_INVITE	Shall be used to assign the asynchronous slot to a node that has indicated a pending NMTCommand / NMTRequest. The addressed node shall answer immediately after the reception of the SoA with the NMTCommand / NMTRequest ASnd DLPDU
SyncRequest	06 _h SYNC_REQUEST	Shall be used to configure/synchronize continuous-time-triggered CNs and/or to query the synchronization data of a CN. The addressed CN shall answer immediately after the reception of the SoA with the node specific SyncResponse ASnd DLPDU
UnspecifiedInvite	FF _h UNSPECIFIED_INVITE	Shall be used to assign the asynchronous slot to a node that has indicated a pending transmit request. The addressed node shall answer immediately after the reception of the SoA, with any kind of a Type 13 fieldbus ASnd or a legacy Ethernet

Description	Value (ID)	Description
		DLPDU
NOTE All ServiceIDs without NoService are handled within the ATC.		

The MNs ASS decides within the known send queue status, which node with which status gets the next asynchronous slot.

6.6.2.2.6 RequestedServiceTarget (svtg)

This parameter indicates the address (DL-address) of the node, which shall send within the asynchronous slot.

C_ADDR_INVALID shall indicate the asynchronous slot is not assigned.

6.6.2.2.7 Type 13 fieldbus Version (eplv)

This parameter indicates the current Type 13 fieldbus version of the MN.

6.6.2.3 Payload

6.6.2.3.1 General

Only in the SyncRequest user data is conveyed by the SoA DLPDU. In all other cases no user data is conveyed by the SoA DLPDU.

6.6.2.3.2 SyncRequest

The parameter is passed/received to/from the DLS-User as the DLSDU parameter of the DLS DL-SYN.

6.6.3 Sending SoA DLPDU

A SoA DLPDU is sent by the MN at the beginning of the asynchronous phase and assigns the asynchronous phase to a specific node, if necessary. The MNs ASS decides in a fair way, which ServiceID of which node shall be served next.

The DLPDU is assembled by requesting the ASS for the next ServiceID and ServiceTarget. The EA and the ER parameters are gathered from the ES. The MNs NMTStatus is requested from the NS.

6.6.4 Receiving the SoA DLPDU

After reception of a PReq DLPDU the CSM waits for the reception of a SoA DLPDU. Reception of a SoA DLPDU confirms the end of the isochronous phase.

The RequestedServiceTarget parameter of the received SoA DLPDU is analyzed. Dependend on the requested ServiceID, the transmission of an ASnd DLPDU shall occur immediately after the transmission / reception of a SoA DLPDU. The ATC is requested for the requested ServiceID.

The EA and the EN parameters are passed to the ES via CSM-ERR and the NMTStatus is passed to the NS for further processing.

The MN shall observe network traffic in order to ensure, that there is no other MN active on the network. Reception of a SoC or a SoA DLPDU indicates that there is another MN active.

Because of the distinct MAC address of each node it is not possible that two or more nodes own the same MAC address but it is still possible that two or more nodes own the same Type 13 fieldbus address. Only in the asynchronous communication multiple CNs can answer on a SoA DLPDU. Since the MN sends a MAC Broadcast (SoA DLPDU) to a Unicast Type 13 fieldbus address, several CNs with the same Type 13 fieldbus address are able to respond. The MN shall detect multiple used Type 13 fieldbus addresses in a network by counting the responses on an IdentRequest SoA DLPDU.

6.7 Asynchronous send (ASnd)

6.7.1 General

There are two types of asynchronous DLPDUs available:

- a non Type 13 fieldbus DLPDU may be sent,
- a Type 13 fieldbus DLPDU in the form of a ASnd DLPDU.

Although only one asynchronous DLPDU per Type 13 fieldbus cycle is allowed, the CSM of the CN does not limit the amount of received DLPDUs within the asynchronous phase of the cycle.

Upon assignment of the asynchronous slot via the SoA DLPDU, the requested node arranges the requested information and sends it via a non Type 13 fieldbus DLPDU or via an ASnd DLPDU. Different ServiceIDs in an ASnd DLPDU are possible.

- **StatusResponse:** Is used to distribute the current status and detailed error information of a node.
- **IdentResponse:** Is used to distribute identification data of inactive CNs waiting to be included into the network and/or to query the identification data of a CN.
- **NMTCommand:** Is used by the MN NMT to distribute common NMT information and to force specific commands to a single, to specific or to all nodes on the Type 13 fieldbus network.
- **NMTRequest:** Is used to give CNs the possibility also to request the above functions. The requested function is decoded in the payload and distributed by the MN in one of the next asynchronous slots via ASnd-DLPDU.
- **SDO:** Is used for peer to peer communication with access to the object dictionary of a device.
- **SyncResponse:** Is used to distribute the current synchronization data of a continuous-time-triggered CN.

The addressed node shall answer immediately after the reception of the SoA.

6.7.2 Structure of the ASnd DLPDU

6.7.2.1 General

The structure of ASnd DLPDU is shown in Table 14.

Table 14 – Structure of ASnd DLPDU

DLPDU field	Data type	Value/description
Message Type	OCTET[1]	06h / identify the ASnd DLPDU
Destination	OCTET[1]	Node ID of the addressed node
Source	OCTET[1]	Node ID of the transmitting node
ServiceID	OCTET[1]	Service ID
Payload	OCTET[1 to P(C_DLL_MAX_PAYL_OFFSET)-4]	DLSDU

6.7.2.2 Parameters of ASnd DLPDU

6.7.2.2.1 Destination (dest)

This parameter indicates the node ID of the addressed node (see 5.3.3.2). For ASnd DLPDU the destination depends on the used ServiceID (see 6.7.2.2.3).

6.7.2.2.2 Source (src)

This parameter indicates the node ID of the transmitting node (see 5.3.3.3).

6.7.2.2.3 ServiceID (svid)

This parameter indicates the ServiceID dedicated to the asynchronous slot.

Table 15 shows the definitions of the ServiceID entries.

Table 15 – Definition of the ServiceID in the ASnd DLPDU

Description	Value (ID)	Destination	Description
IdentResponse	01 _h (IDENT_RESPONSE)	Type 13 fieldbus broadcast	Within the IdentResponse ServiceID the CN distributes identification data. This ServiceID shall be issued by a node that received an IdentRequest via SoA
StatusResponse	02 _h (STATUS_RESPONSE)	Type 13 fieldbus broadcast	Within the StatusResponse ServiceID the CN distributes the current status and detailed error information. This ServiceID shall be issued by a node that received a StatusRequest via SoA
NMTRequest	03 _h (NMT_REQUEST)	Type 13 fieldbus MN	Within the NMTRequest ServiceID the CN asks the MN to request the specified ServiceID within the next asynchronous phase. This ServiceID shall be issued by a CN that received a NMTRequestInvite via SoA
NMTCommand	04 _h (NMT_COMMAND)	(see Note 2)	Within the NMTCommand ServiceID the MN NMT distributes common NMT information and forces specific commands to a single, to specific or to all nodes on the Type 13 fieldbus network. This ServiceID shall be issued by the MN upon an internal request or upon an external request via NMTRequest
SDO	05 _h (SDO)	Type 13 fieldbus CNs and Type 13 fieldbus	Within the SDO ServiceID, a peer to peer communication with access to the object dictionary of a device is issued. This ServiceID may be issued by a node that received an UnspecifiedInvite via SoA

Description	Value (ID)	Destination	Description
		MN	
SyncResponse	06 _h (SYNC_RESPONSE)	Type 13 fieldbus broadcast	Within the SyncResponse ServiceID the CN distributes the current synchronization data. This ServiceID shall be issued by a node that received a SyncRequest via SoA
Manufacturer specific	A0 _h to FE _h	Type 13 fieldbus CNs and Type 13 fieldbus MN	Within the manufacturer specific Service ID the DLS-User may distribute any kind of data. The use of these service IDs is beyond the scope of this document. This ServiceID may be issued by a node that received an UnspecifiedInvite via SoA.
NOTE 1 ServiceIDs not listed are reserved.			
NOTE 2 The destination is depending on the underlying NMT command. Type 13 fieldbus CNs as well as Type 13 fieldbus broadcast is possible.			

6.7.2.2.4 Payload (pl)

6.7.2.2.4.1 General

ASnd DLPDU can transmit user data up to the length of P(C_DLL_ISOCHR_MAX_PAYL).

The following user data are defined for the ASnd DLPDU payload parameter:

6.7.2.2.4.2 IdentResponse

The parameter is passed/received to/from the DLS-User as the DLSDU parameter of the DLS DL-IDE.

6.7.2.2.4.3 StatusResponse

The parameter is passed/received to/from the DLS-User as the DLSDU parameter of the DLS DL-STA.

6.7.2.2.4.4 NMTCommand

The parameter is passed/received to/from the DLS-User as the DLSDU parameter of the DLS DL-CMD.

6.7.2.2.4.5 NMTRrequest

CNs requesting a NMTCommand, an IdentResponse and a StatusResponse handle this request by inviting the MN with a NMTRrequest to accomplish the requested service.

As shown in Table 16 the NMTRrequest user data shall contain the NMTRrequested-CommandID, NMTRrequestedCommandTarget and NMTRrequestedData.

Table 16 – Structure of NMTRrequest user data

DLPDU field	Data type	Value/description
NMTRrequestCommandID	OCTET[1]	
NMTRrequestedCommandTarget	OCTET[1]	
NMTRrequestedCommandData	OCTET[1 to P(C_DLL_MAX_PAYL_OFFSET)-4]	

where:

- NMTRequestedCommandID (rcid): The NMT service shall be issued by the MN by its NMTRequestedCommandID value. StatusResponse and IdentResponse services are indicated by the SoA RequestedServiceID values STATUS_REQUEST and IDENT_REQUEST.
- NMTRequestedCommandTarget (rct): Indicates the target node of the requested NMT command.
- NMTRequestedCommandData (rcd): NMT command specific data to be issued by the MN.

6.7.2.2.4.6 SDO

The parameter is passed/received to/from the DLS-User as the DLSDU parameter of the DLS DL-SDO.

6.7.2.2.4.7 SyncResponse

The parameter is passed/received to/from the DLS-User as the DLSDU parameter of the DLS DL-SYN.

6.7.2.2.4.8 Manufacturer specific

The parameter is passed/received to/from the DLS-User as the DLSDU parameter of the DLS DL-UDT.

6.7.3 Sending ASnd DLPDU

After invited by a SoA DLPDU, the requested CN sends an ASnd DLPDU, with ServiceID set to:

- IdentResponse: Within the ATC, the user data is requested with the DLS DL-IDE. The responded user data is assembled with the ServiceID=IdentResponse to the ASnd DLPDU.
- StatusResponse: Within the ATC, the user data is requested with the DLS DL-STA. The responded user data is assembled with the ServiceID=StatusResponse to the ASnd DLPDU.
- NMTRequest: Requested NMTRequests from the DLS-User are queued in the ATC. Within the ATC, the oldest queue content is responded and this user data is assembled with the ServiceID=NMTRequest to the ASnd DLPDU.
- NMTRequest: Requested NMTRequests, StatusRequest and IdentRequests from CNs are queued in the ATC. Within the ATC, the oldest queue content is translated into a NMTRequest user data and this is assembled with the ServiceID=NMTRequest to the ASnd DLPDU to be executed at the MN.
- SDO: Requested SDO DLSDUs from the DLS-User are queued in the ATC. Within the ATC, the oldest queue content is responded and this user data is assembled with the ServiceID=SDO to the ASnd DLPDU.
- SyncResponse: Within the ATC, the user data is requested with the DLS DL-SYN. The responded user data is assembled with the ServiceID=SyncResponse to the ASnd DLPDU.
- Manufacturer specific: Requested UDT DLSDUs from the DLS-User are queued in the ATC. Within the ATC this user data is assembled with the ServiceID="Manufacturer specific" to the ASnd DLPDU.

6.7.4 Receiving the ASnd DLPDU

If an ASnd frame has been received it shall be processed depending on the ServiceID as follow:

- **IdentResponse:** Received IdentResponse ASnd DLPDUs are passed to the DLS-user via the DL-IDE primitive of the ATC. The MN shall receive the IdentResponse. CNs may receive IdentResponse if configured to do so.
- **StatusResponse:** Received StatusResponse ASnd DLPDUs are passed to the DLS-user via the DL-STA primitive of the ATC. The MN shall receive the StatusResponse. CNs may receive StatusResponse if configured to do so.
- **NMTCommand:** Received NMTCommand ASnd DLPDUs are passed to the DLS-user via the DL-CMD primitive of the ATC.
- **NMTRequest:** Received NMTRequest ASnd DLPDUs are interpreted by the MNs ATC and pushed into the Status, Ident or the NMTCommand queue, depending on the requesting NMTRequestedCommandID. CNs do not receive this DLPDU.
- **SDO:** Received SDO ASnd DLPDUs are passed to the DLS-user via the DL-SDO primitive of the ATC.
- **SyncResponse:** Received SyncResponse ASnd DLPDUs are passed to the DLS-user via the DL-SYN primitive of the ATC. The MN shall receive the SyncResponse. CNs shall receive SyncResponse if supporting continuous-time-triggered communication.
- **Manufacture specific:** Received UDT ASnd DLPDUs are passed to the DLS-user via the DL-UDT primitive of the ATC.

7 DLE elements of procedure

7.1 Overall structure

The DLL is composed of control elements of isochronous transmission TX/RX control (ITC), asynchronous transmission TX/RX Control (ATC), cycle state machine (CSM), asynchronous slot scheduler (ASS), exception signaling (ES), NMT signaling (NS) and DLL Management Interface.

The CSM as the primary control element provides the function for deterministic medium access control cooperating with the ITC, the ATC, the ES and the NS for reliable and efficient support both of isochronous and asynchronous data transfer services.

The DLL management interface provides DLL management functions.

7.2 Cycle state machine (CSM)

7.2.1 Overview

7.2.1.1 Cycle state machine of the MN (MN-CSM)

The cycle state machine of the MN (MN-CSM) shall manage the communication within a Type 13 fieldbus cycle. The MN-CSM generates the flow of the frames during a Type 13 fieldbus cycle and monitors the reaction of the CNs. The flow order is dependent on the state of the NMT (signaled via the primitive CSM-TNMT).

7.2.1.2 Cycle state machine of the CN (CN-CSM)

The cycle state machine of the CN (CN-CSM) handles communication within a Type 13 fieldbus Cycle. The CN-CSM tracks the order of the frames received within a cycle and reacts as described below. The expected order of frame reception is dependent on the state of the NMT (signaled via the primitive CSM-TNMT).

7.2.2 Primitive definitions

7.2.2.1 Primitive definitions between CSM and ITC

Table 17 summarizes all primitives exchanged between the CSM and the ITC.

Table 17 – Primitives exchanged between CSM and ITC

Primitive name	Source	Associated parameters	Description
CSM-PDO.ind	ITC	Isochr Isochr-time-triggered Isochr-Out	Indicates the assignment of the next isochronous slot.
CSM-TPDO.ind	ITC	D_addr DLSDU	Indication of a PDO element with its associated parameters for transmission at the next isochronous slot. MN: The requested PDO element is determined by the ITC internal slot counter. CN: Only the CN dependent PDO is requested once per Type 13 fieldbus cycle.
CSM-RPDO.ind	CSM	S_addr D_addr DLSDU	Carries forward a received PDO element with its associated parameters to the ITC.

The parameters used with the primitives exchange between the CSM and the ITC are described in Table 18.

Table 18 – Parameters used with primitives exchanged between CSM and ITC

Parameter name	Description
S_addr	The S_addr parameter specifies the DL-address of the publisher.
D_addr	The D_addr parameter specifies the DL-address of the subscriber.
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.
Isochr	This parameter specifies with a value unequal zero that there are nodes in the isochronous list of the current cycle.
Isochr-time-triggered	This parameter specifies with a value unequal zero that there are nodes in the isochronous list of the current cycle which are of communication class <i>continuous-time-triggered</i> .
Isochr-Out	This parameter specifies with a value unequal zero that the MN is configured to send a PRes.

7.2.2.2 Primitive definitions between CSM and ATC

Table 19 summarizes all primitives exchanged between the CSM and the ATC.

Table 19 – Primitives exchanged between CSM and ATC

Primitive name	Source	Associated parameters	Description
CSM-TASND.ind	ATC	Destination ServiceID Payload	Indicates an ASnd DLPDU with its associated parameters from the ATC internal queue for transmission at the next asynchronous slot.
CSM-RASND.ind	CSM	Destination Source ServiceID Payload	Carries forward a received ASnd DLPDU with its associated parameters to the ATC.
ATC-Prio.req	CSM	(none)	Requests the priority and the number of pending frames in the asynchronous send queue with the highest priority from the ATC. CN: This primitive is called just before sending the PRes DLPDU and StatusResponse ASnd DLPDU. MN: This primitive is called just before sending the SoA DLPDU.
ATC-Prio.ind	ATC	Priority RequestToSend	Indicates the priority and the number of pending frames in the asynchronous send queue with the highest priority. CN: The parameters are transmitted via the PRes and StatusResponse ASnd DLPDU. The MNs CSM carries this parameter forward to the ASS via CSM-Prio. MN: The MNs internal CSM carries forward this parameter to the ASS via CSM-Prio.

The parameters used with the primitives exchanged between the CSM and the ATC are described in Table 20.

Table 20 – Parameters used with primitives exchanged between CSM and ATC

Parameter name	Description
Destination	This parameter indicates the Node ID of the addressed node.
Source	This parameter indicates the Node ID of the transmitting node.
ServiceID	This parameter indicates the ServiceID dedicated to the asynchronous slot.
Payload	This parameter indicates the user data.
Priority	This parameter indicates the priority of the user data in the asynchronous send queue with the highest priority.
RequestToSend	This parameter indicates the number of pending user data in the asynchronous send queue with the highest priority.

7.2.2.3 Primitive definitions between CSM and ASS

Table 21 summarizes all primitives exchanged between the CSM and the ASS.

Table 21 – Primitives exchanged between CSM and ASS

Primitive name	Source	Associated parameters	Description
CSM-CSM.ind	CSM	Resp-Expected Async-In Async-Out	Indicates the assignment of the next asynchronous slot
CSM-Prio.ind	CSM	Source Priority RequestToSend	Indicates the received priority and Request to Send parameter from the specified source
CSM-SoA.req	CSM	(none)	Request the service and node, which shall transmit the ASnd frame inside the next asynchronous slot
CSM-SoA.ind	ASS	Requested-ServiceID Requested-ServiceTarget	Indicates the type of user data with the ServiceID parameter and the addressed node with the ServiceTarget parameter, who shall send on the next asynchronous slot. The parameters are transmitted via the pending SoA DLPDU

The parameters used with the primitives exchange between the CSM and the ASS are described in Table 22.

Table 22 – Parameters used with primitives exchanged between CSM and ASS

Parameter name	Description
RequestedServiceID	This parameter indicates the asynchronous service ID dedicated to the following asynchronous slot
RequestedServiceTarget	This parameter indicates the Node ID of the node, which shall send within the following asynchronous slot
Resp-Expected	Resp-expected = "TRUE" means that there is an ASnd DLPDU expected upon the next asynchronous slot
Async-In	This indicates, that a SoA DLPDU must be sent in this cycle and an ASnd DLPDU or a non Type 13 fieldbus frame could be received
Async-Out	This indicates, that a SoA DLPDU must be sent in this cycle and an ASnd DLPDU must be sent in this cycle
Priority	This parameter indicates the priority of the user data in the asynchronous send queue with the highest priority
RequestToSend	This parameter indicates the number of pending user data in the asynchronous send queue with the highest priority

7.2.2.4 Primitive definitions between CSM and ES

Table 23 summarizes all primitives exchanged between the CSM and the ES.