

INTERNATIONAL STANDARD

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**Industrial communication networks – Fieldbus specifications –
Part 4-19: Data-link layer protocol specification – Type 19 elements**

**Réseaux de communication industriels – Spécifications des bus de terrain –
Partie 4-19: Spécification des protocoles des couches de liaison de données –
Éléments de Type 19**



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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-19: Data-link layer protocol specification – Type 19 elements

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International Standard IEC 61158-4-19 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This first edition and its companion parts of the IEC 61158-4 subseries cancel and replace IEC 61158-4:2003. This edition of this part constitutes a technical addition. This part and its companion Type 19 parts also cancel and replace IEC PAS 62410, published in 2005.

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

- a) deletion of the former Type 6 fieldbus, and the placeholder for a Type 5 fieldbus data link layer, for lack of market relevance;
- b) addition of new types of fieldbuses;
- c) division of this part into multiple parts numbered -4-1, -4-2, ..., -4-19.

This bilingual version (2014-12) corresponds to the monolingual English version, published in 2007-12.

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

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

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

The French version of this standard has not been voted upon.

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- withdrawn;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.

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INTRODUCTION

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

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

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

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

Withdrawn

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-19: Data-link layer protocol specification – Type 19 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) 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 part of this standard does not contain tests to demonstrate compliance with such requirements.

2 Normative references

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

IEC 61158-4-16, *Industrial communications networks – Fieldbus specifications – Part 4-16: Data-link layer protocol specification – Type 16 elements*

IEC 61800-7-20x (all subparts), *Adjustable speed electrical power drive systems – Part 7-20x: Generic interface and use of profiles for power drive systems – Profile type x specification*¹

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

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

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

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:

3.2 Additional Type 19 terms and definitions

3.2.1

broadcast

transmission to all devices in a network without any acknowledgment by the receivers

3.2.2

communication cycle

fixed time period between two master synchronization telegrams in which real-time telegrams are transmitted in the RT channel and non real-time telegrams are transmitted in the IP channel

3.2.3

control unit

control device (e.g., a PLC as specified in the IEC 61131 standard family)

3.2.4

control word

two adjacent OCTETs inside the master data telegram containing commands for the addressed device

¹ At present, these subparts are IEC 61800-7-201, 7-202, 7-203 and 7-204.

3.2.5**cross communication**

direct data transfer between slave devices (without active involvement of master)

3.2.6**cycle time**

duration of a communication cycle

3.2.7**cyclic communication**

periodic exchange of telegrams

3.2.8**cyclic data**

part of a telegram, which does not change its meaning during cyclic operation of the network

3.2.9**cyclic operation**

operation in which devices in the communication network are addressed and queried one after the other at fixed, constant time intervals

3.2.10**device**

a slave in the communication network, (e.g., a power drive system as defined in the IEC 61800 standard family, I/O stations as defined in the IEC 61131 standard family)

3.2.11**device address field**

address field (eight bits) containing the address of the device

3.2.12**device control**

four adjacent OCTETs inside the master data telegram containing commands for each device

3.2.13**device status**

four adjacent OCTETs inside the acknowledge telegram containing status information for each device

3.2.14**DLE station identifier**

network address assigned to a DLE

3.2.15**DLE station slot**

unit (granularity of one) of position dependent mapping (for cyclic data field) of which a DLE may occupy one or more, delineated by the range beginning at the DLE station identifier with a length equal to the configured number of occupied slots

3.2.16**element**

part of IDNs – each IDN has 7 elements, whereas each one has a specific meaning (e.g., number, name, data)

3.2.17**EtherType**

part of the Type 19 specific telegram header

3.2.18

forwarding

mode by which a device passes on a received telegram to the other port, either changed or unchanged

3.2.19

identification number (IDN)

designation of operating data under which a data block is preserved with its attribute, name, unit, minimum and maximum input values, and the data

3.2.20

line, line structure

network topology, in which the transmission medium is routed from station to station in the form of a line; the information is transmitted in one direction from the master down to the last slave in the line, and then flows back to the master via all the slaves in the reverse order (CP16/3)

3.2.21

loopback

mode by which a device passes on a received telegram to the same port and to the other port, either changed or unchanged

3.2.22

master

node, which assigns the other nodes (i.e., slaves) the right to transmit

3.2.23

master data telegram (MDT)

telegram, in which the master inserts its data

3.2.24

master DLE

DLE that performs the functions of network master

3.2.25

master synchronization telegram (MST)

telegram, or part of a telegram, in which the master inserts a time synchronization signal

3.2.26

MDT0 telegram

telegram, in which the master transmits its synchronization data, as well as parts or all of its real-time data, to the slaves

3.2.27

participant

node

3.2.28

physical layer

first layer of the ISO-OSI reference model

3.2.29

protocol

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

3.2.30**real-time data**

part of the telegram that does not change its meaning during cyclic operation of the interface

3.2.31**RT channel**

defined time slot within the communication cycle, which passes the CPF16 real-time telegrams

3.2.32**service channel (SVC)**

non real-time transmission of information upon master request during RT channel

3.2.33**slave**

node, which is assigned the right to transmit by the master

3.2.34**slave DLE**

DLE that performs the functions of network slave

3.2.35**station**

node

3.2.36**status word**

two adjacent OCTETs inside the acknowledge telegram containing status information of a device

3.2.37**S-0-nnnn**

designation of IDNs

3.2.38**telegram**

DLPDU

3.2.39**topology**

physical network architecture with respect to the connection between the stations of the communication system

3.3 Symbols**3.3.1 ADR**

device address ($1 \leq \text{ADR} \leq 254$) adjusted directly on the device e.g., using a selector switch

3.3.2 AT MST

header in AT

3.3.3 AT0...3

acknowledge telegrams

3.3.4 INFO

service channel information

3.3.5 $J_{t_{scyc}}$

jitter in t_{scyc}

3.3.6 MDT0

master data telegram with synchronization data that the slaves evaluates

3.3.7 MDT1...3

master data telegrams without synchronization data

3.3.8 P1

port 1

3.3.9 P2

port 2

3.3.10 RxD

received data

3.3.11	SLKN	slave identification parameter, slave arrangement
3.3.12	SVC	service channel
3.3.13	t_1	AT transmission starting time
3.3.14	t_{1min}	shortest AT transmission starting time
3.3.15	t_3	command value valid time
3.3.16	t_4	feedback acquisition capture point
3.3.17	t_5	minimum feedback processing time
3.3.18	t_{ATAT}	transmit to transmit recovery time in a slave with several slaves
3.3.19	t_{cable}	time, by which the transmitted signal is delayed by the cable, for each unit of length (approx., 5 ns/m)
3.3.20	t_{Ncyc}	control unit cycle time
3.3.21	t_{rep}	time, by which the received signal is delayed by a forwarding slave (input-output)
3.3.22	t_{ring}	time, which a master telegram needs, until it has passed through the network and reached the master again
3.3.23	t_{Scyc}	communication cycle time
3.3.24	TxD	transmitted data

3.4 Abbreviations

3.4.1	AHS	service transport handshake of the device (acknowledge HS)
3.4.2	AT	acknowledge telegram
3.4.3	C1D	class 1 diagnostic
3.4.4	CC	cross communication between participants
3.4.5	CP	communication phase
3.4.6	CPS	communication phase switching
3.4.7	CRC	cyclic redundancy check
3.4.8	FCS	DLPDU check sequence
3.4.9	HS	service channel handshake (see AHS and MHS)
3.4.10	IDN	identification number
3.4.11	MDT	master data telegram
3.4.12	MDT MST	header in MDT
3.4.13	MHS	service transport handshake of the master
3.4.14	MS	communication from slave to master
3.4.15	MST	master synchronization telegram
3.4.16	NRC	non real-time channel
3.4.17	NRT	non real-time mode
3.4.18	RT	real-time
3.4.19	RTC	real-time channel
3.4.20	RTD	real-time data in MDT or AT
3.4.21	SERCOS	serial real-time communication system interface
3.4.22	SFD	start DLPDU delimiter
3.4.23	SVC	service channel

3.5 Additional conventions

3.5.1 DLPDU support level

There are two levels of cycle time support for a DLPDU:

- level B – 50 ns jitter synchronization class (master and slave);
- level C – 50 μ s jitter synchronization class (master and slave).

Refer to 8.2.7 for additional information.

3.5.2 DLPDU IDN concept

All data types are assigned identification numbers (IDNs). They include real-time data (commands and feedback values), parameters, and procedures. Most IDNs are similar to those for Type 16 (see IEC 61158-4-16, 2.4). Several IDNs relate to the application and are defined in their relevant standards (e.g., IEC 61800-7-20x for Power Drive Systems).

Refer to Annex A for additional information, as well as to IEC 61158-4-16, Annex A.1 for detailed IDN specification.

4 DL-protocol overview

This protocol type provides a highly optimized means of interchanging fixed-length real-time data and variable-length segmented messages between a single master device and a set of slave devices, interconnected in a ring or a line topology. The ring topology provides for redundant communication paths, and in case of a fault it automatically switches to a set of two lines without disturbing the communication.

This protocol type also provides for direct real-time data transmission between slaves, inside the real-time channel (RTC), within each cycle.

The exchange of real-time data is totally synchronous by configuration and is unaffected by the messaging traffic.

The device addresses are set by the user, for example, using a selector. Additional devices may be added whenever required, even during operation, without affecting the address selections, which already exist. The determination of the number, identity and characteristics of each device may be configured or may be detected automatically at start-up.

Slave interfaces shall be used to connect the slave devices to the network. At the physical layer, a slave represents the connection of one or more devices to the network. Logically, one slave with several devices shall act the same as several slaves with one device each.

This protocol type also provides a non real-time channel (NRC), in which any Standard Ethernet DLPDUs can be exchanged between Type 19 devices and any other connected Ethernet network nodes.

There are two classes of Type 19 DLE:

- a) master DLE;
- b) slave DLE.

Only the master DLE is able to initiate the cyclic transmission.

Type 19 telegrams are Ethernet DLPDUs according to ISO/IEC 8802-3. Type 19 real-time telegrams shall be transmitted in the real-time part of the communication cycle time. They

- Master data telegram (MDT), in which the master transmits real-time data to the slaves;
- Device telegram (AT), in which the slaves transmit real-time data to other devices.

Type 19 specifies 4 MDTs (MDT0 to MDT3). The MDTs shall be transmitted by the master and received by each slave. The MDTs shall contain all information (e.g., synchronization, command values, digital outputs) which is sent from the master to the slaves through the real-time channel.

Type 19 specifies 4 ATs (AT0 to AT3). The ATs shall be transmitted by the master with empty data fields. Each slave shall insert its data into its allocated data field within the AT. The ATs shall contain all information (e.g., feedback values, digital inputs) which is sent from the slaves to the master as well as to other slaves through the real-time channel.

The allocations of the service channels (SVC) and the real-time data fields (RTD) in the MDT as well as in the AT shall be configured with parameters. The RTD lengths in the MDTs and the ATs shall depend on the configuration and may be different for each slave depending upon configuration. The number of MDTs and ATs may also be different. This configuration shall meet the following requirements.

- a) All service channels shall be configured directly after the hot-plug field.
- b) All real-time data fields shall be configured directly after the last service channel.
- c) All SVCs of a device shall be transmitted within one MDT and one AT. The telegrams shall be filled up with SVCs as much as possible before using the next MDT and AT.
- d) All RTDs of a device shall be transmitted within one MDT and one AT. The telegrams shall be filled up with RTDs as much as possible before using the next MDT and AT.

Telegram combinations of MDTs and ATs shall fit to any one of the four possibilities shown in Figure 1, exclusively.

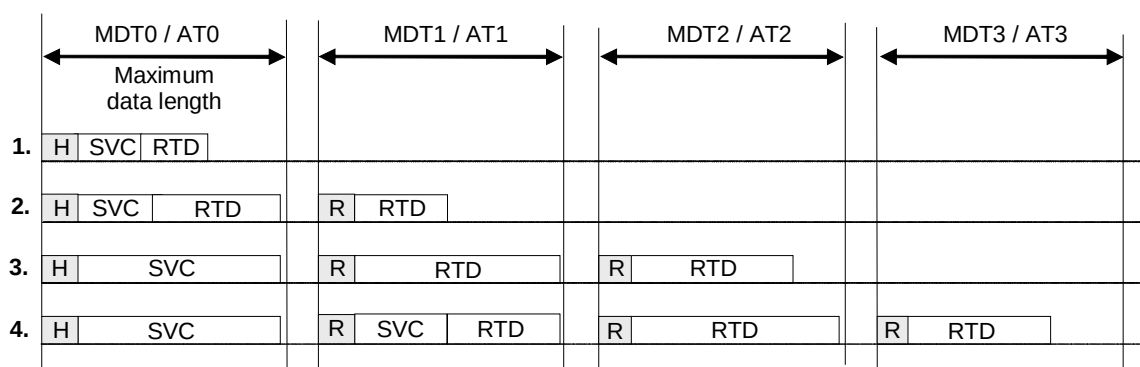


Figure 1 – Valid MDT and AT telegram combinations

5 DLPDU structure

5.1 Overview

Networks of this protocol type use standard ISO/IEC 8802.3 Ethernet DLPDUs for transporting Type 19 DLPDUs.

5.2 General DLPDU identification

5.2.1 Introduction

DLPDUs shall be identified as specified in Table 1.

Table 1 – Ethernet DLPDU identification

DLPDU field	Data type	Value/description
Dest MAC	OCTET[6]	Destination MAC address
Src MAC	OCTET[6]	Source MAC address
EtherType	WORD	0x88CD (Type 19)

5.2.2 Destination address (Dest MAC)

The master shall transmit DLPDUs to all slaves using the broadcast address 0xFFFF FFFF FFFF as the destination address.

5.2.3 Source address (Src MAC)

The source address shall always be the MAC address of the master.

5.2.4 EtherType

The EtherType for real-time DLPDUs shall contain the value 0x88CD, which is the unique type field number that has been allocated by the IEEE EtherType Field Registration Authority for Type 19 telegrams.

NOTE This field number refers to Type 19 communication.

5.3 General DLPDU structure

5.3.1 Introduction

The data structure in a DLPDU shall consist of the following data entries as specified in Table 2.

Table 2 – Data structure in a DLPDU

Data field	Data type	Value/description
Header	OCTET[6]	Defines the DLPDU type
Payload	OCTET[40-1494]	Data fields are padded

5.3.2 DLPDU header

The DLPDU header shall specify two types of telegrams, as specified in 5.4:

- **Master data telegram (MDT):** MDTs shall transmit data from the master to the slaves;
- **Device telegram (AT):** ATs shall transmit data from the slaves back to the master, as well as to the other slaves.

5.3.3 DLPDU payload

All transmitted data are permitted to have arbitrary bit sequences.

Padding OCTETs shall be added if the Type 19 data is less than 40 OCTETs, in order to reach a total data field length of at least 46 OCTETs.

The DLPDU payload shall be as described in 5.5 and 5.6.

5.4 DLPDU header

5.4.1 Introduction

The DLPDU header shall distinguish the various DLPDUs. It shall be coded in the telegram whether it is in the primary or secondary channel, whether it is an MDT or an AT, and which one (MDT0 to MDT3, respectively AT0 to AT3).

In a line topology, the master shall decide whether the telegrams are marked as primary or secondary telegrams, depending upon configuration.

The DLPDU header structure is shown in Table 3:

Table 3 – DLPDU payload header

Data field	Data type	Value/description
DLPDU type	OCTET[1]	
Reserved	OCTET[1]	
Reserved	OCTET[4]	

5.4.2 Type 19 type

The Type 19 type shall be generated by the master and transmitted in every MDT. Its content shall be as shown in Table 4.

Table 4 – DLPDU type

Bit number.	Value	Description
7		Primary or secondary telegram
	0	Telegram on the primary channel (P-Telegram)
	1	Telegram on the secondary channel (S-Telegram)
6		MDT or AT
	0	MDT
	1	AT
5-2		Reserved
1-0		Telegram number
	00	Telegram number 0
	01	Telegram number 1
	10	Telegram number 2
	11	Telegram number 3

5.5 MDT DLPDU

5.5.1 MDT MST field summary

The MDT is a Type 19 telegram and shall be as specified in Table 5, whereas the Type 19 header is called MDT MST.

Table 5 – MDT MST header

DLPDU part	Data field	Data type	Value/Description
MDT MST header	MDT type	OCTET[1]	
	MDT phase	OCTET[1]	
	MDT CRC	OCTET[4]	

5.5.2 Evaluation of MDT MST in the slaves

The MDT MST shall be generated by the master and evaluated by the slaves. Each slave shall evaluate the MDT MST according to Table 6.

Table 6 – MDT MST fields to be considered by the slave

	MDT type	MDT phase	MDT CRC
MDT0	yes	yes	yes
MDT1	yes	no	no
MDT2	yes	no	no
MDT3	yes	no	no

5.5.3 MDT type

Refer to 5.4.2, whereas bit #6 shall be 0.

5.5.4 MDT phase

The MDT phase shall contain the status of the Type 19 communication during initialization and during normal operation. The phase shall be generated by the master and transmitted in every MDT. The structure is shown in Table 7.

Table 7 – MDT phase

Bit No.	Value	Description
7		Communication phase switching (CPS)
	0	Current CP
	1	New CP
6-4		Reserved
3-0		Communication phase (CP)
	0000	CP0
	0001	CP1
	0010	CP2
	0011	CP3
	0100	CP4
	0101 to 1111	Reserved

5.5.5 MDT CRC

The cyclic redundancy check (CRC) shall be used by the transmit and receive algorithms to generate a CRC value for the MDT CRC field. The MDT CRC field shall contain a 4-OCTET (32-bit) cyclic redundancy check (CRC) value. This value shall be computed as a function of the contents of the destination address (see 5.2.2), source address (see 5.2.3), EtherType (see 5.2.4), Type 19 type (see 5.4.2) and phase (see 5.5.4). The encoding shall be as defined by the Standard Ethernet CRC generating polynomial (see ISO/IEC 8802-3).

The MDT CRC shall be generated by the master and transmitted in every MDT (MDT0 to MDT3). This CRC shall be monitored in MDT0 only, for synchronization purposes.

5.5.6 MDT payload during initialization

5.5.6.1 General

The content of the MDT data field depends on the communication phase and is described in the following subclauses.

5.5.6.2 CP0

The master shall always transmit MDT0 telegrams, and no MDT1, MDT2, nor MDT3 telegrams. MDT0 shall be structured as stated in Table 8.

Table 8 – MDT0 in CP0

DLPDU part	Data Field	Data Type	Value/Description
MDT	Type 19 MDT0	OCTET[1]	
	MDT phase	OCTET[1]	CP0
	MDT CRC	OCTET[4]	
MDT payload	MDT Data Field	OCTET[40]	Shall be padded and not used

5.5.6.3 CP1 and CP2

In CP1 and CP2, the master shall always transmit MDT0 and MDT1 telegrams, but no MDT2, nor MDT3 telegrams.

The MDT data field of the MDT0 shall contain the service channel (see 0) and the device control (see 5.5.7.4.2) of device addresses 0 to 127. The MDT data field of the MDT1 shall contain the service channel and the device control of device addresses 128 to 255. See

Table 9 and Table 10.

A slave shall behave as requested if the handshake bit (MHS) is set to 1 in the corresponding SVC INFO and the device control are “don't care”.

Telegrams in CP2 shall have the same structure as in CP1, but the contents of SVC INFO shall be valid only in CP2.

The content of device control shall be “don't care”.

Withdrawn

Table 9 – MDT0 in CP1 and CP2

DLPDU part	Data Field	Data Type	Value/Description
MDT MST	Type 19 MDT0	OCTET[1]	
	MDT phase	OCTET[1]	CP1 or CP2
	MDT CRC	OCTET[4]	
MDT data field	Device #0 service, service control	OCTET[2]	
	Device #0 SVC INFO	OCTET[4]	
	...		(And so on for devices #1 to #126)
	Device #127 service, service control	OCTET[2]	
	Device #127 SVC INFO	OCTET[4]	
	Device #0 device control	OCTET[4]	
	...		(And so on for devices #1 to #126)
	Device #127 device control	OCTET[4]	

Table 10 – MDT1 in CP1 and CP2

DLPDU part	Data Field	Data Type	Value/Description
MDT MST	Type 19 MDT1	OCTET[1]	
	MDT phase 1 or 2	OCTET[1]	CP1 or CP2
	MDT CRC	OCTET[4]	
MDT data field	Device #128 service, service control	OCTET[2]	
	Device #128 SVC INFO	OCTET[4]	
	...		(And so on for devices #129 to #254)
	Device #255 service, service control	OCTET[2]	
	Device #255 SVC INFO	OCTET[4]	
	Device #128 device control	OCTET[4]	
	...		(And so on for devices #129 to #254)
	Device #255 device control	OCTET[4]	

5.5.6.4 CP3 and CP4

In CP3 and CP4, the master shall transmit MDTs as in normal operation (see 5.5.7).

In CP3 only the service channel and the device control shall be used. The configurable real-time data of the MDT do not matter, but they shall have the number of OCTETs required for CP4 and normal operation. The positions of the service channels and the real-time data fields in the MDT relevant to the individual slaves shall be as transmitted by the master to the slaves during CP2 with the corresponding communication parameters.

Depending on the application profile some bits in the device control may be valid starting at CP3 and up to CP4.

In CP4, the configurable real-time data shall be valid and filled with command values as determined by the parameters that the master transmitted to the slaves during CP2. The

positions of the service channels and the real-time data fields in the MDT relevant to the individual slaves shall be as transmitted by the master to the slaves during CP2 with the corresponding communication parameters. The device control that depends on the application profile shall be valid.

5.5.7 MDT payload in normal operation

5.5.7.1 Introduction

The MDT payload (see Table 11) shall always contain an MDT hot-plug field (see 5.5.7.2), and either one or both of the following fields:

- an MDT service channel field (see 5.5.7.2.4);
- an MDT real-time data field (see 5.5.7.4).

Table 11 – MDT data field

DLPDU part	Data Field	Data Type	Value/Description
MDT data field	MDT hot-plug field	OCTET[8]	See 5.5.7.2
	MDT service channel field	OCTET[See 0]	Optional. See Figure 1
	MDT real-time data field	OCTET[See 5.5.7.4]	Optional. See Figure 1

For each slave, IDN S-0-1013 shall set the offset for its service channel. IDN S-0-1009 shall set the offset for its real-time data field. IDN S-0-1010 shall contain the length of the MDT (see Figure 2). These parameters shall be transmitted by the master to the slaves in CP2 during initialization.

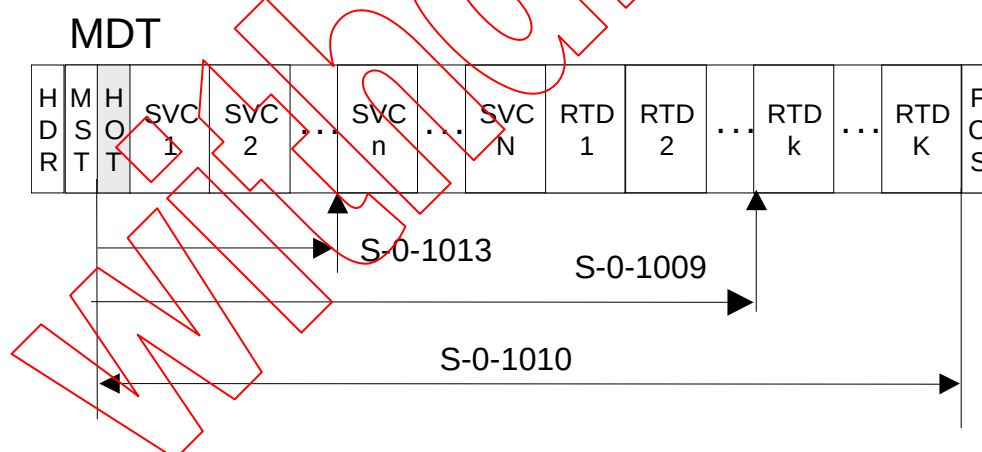


Figure 2 – Offsets within MDT payload

5.5.7.2 MDT hot-plug field

5.5.7.2.1 MDT hot-plug field summary

The structure of the MDT hot-plug field shall be as specified in Table 12 or in Table 13, depending upon hot-plug phase (HP0, HP1, HP2, see 6.3).

Table 12 – MDT hot-plug field in HP0 and HP1

DLDPDU part	Data Field	Data Type	Value/Description
MDT hot-plug field	Device address	OCTET[2]	
	HP control	OCTET[2]	
	HP INFO	OCTET[4]	

Table 13 – MDT hot-plug field in HP2

DLDPDU part	Data Field	Data Type	Value/Description
MDT hot-plug field	Device address	OCTET[2]	
	SVC control	OCTET[2]	
	SVC INFO	OCTET[4]	

5.5.7.2.2 Device address field

The content of device address field shall be as specified in Table 14:

Table 14 – Device address field

Bit No.	Value	Description
31-16		Reserved
15-0		Same as Type 16 (see IEC 61158-4-16, 4.1.3)

5.5.7.2.3 HP control field (in HP0 and HP1)

The content of HP control field shall be as specified in Table 15.

Table 15 – HP control field (in HP0 and HP1)

Bit No.	Value	Description
16-31		Reserved
15-11		Reserved
10		HP field vs. SVC communication
	0	Transmission via HP field
	1	Switch to SVC
9-6		Reserved
5-0		HP function codes
	00 0000	No data
	00 0001	t_{Scyc}
	00 0010	t_1
	00 0011	t_6
	00 0100	t_7
	00 0101	Reserved
	00 0110	Reserved
	00 0111	Reserved
	00 1000	MDT0 length
	00 1001	MDT1 length
	00 1010	MDT2 length
	00 1011	MDT3 length
	00 1100	AT0 length
	00 1101	AT1 length
	00 1110	AT2 length
	00 1111	AT3 length
	10 0001	MDT-SVC pointer
	10 0010	MDT-RTD pointer
	10 0011	AT-SVC pointer
	10 0100	AT-RTD pointer
	all other values	Reserved

5.5.7.2.4 HP INFO fields (in HP0 and HP1)

Refer to the MDT service channel INFO field as described in 5.5.7.3.3.

5.5.7.2.5 Hot plug SVC control field in HP2 (in HP2)

Refer to the MDT service channel field as described in 5.5.7.3.2.

5.5.7.2.6 Hot plug SVC INFO field in HP2 (in HP2)

Refer to the MDT service channel field as described in 5.5.7.3.3.

5.5.7.3 MDT service channel (SVC) field

5.5.7.3.1 MDT service channel field summary

The MDT service channel field (see Table 16) shall contain all service channels (SVC) of the configured devices within a Type 19 network. Each device shall have its own dedicated service channel. The service channel for each device shall be as specified in Table 17.

Table 16 – MDT service channel field

DLPDU part	Data Field	Data Type	Value/Description
MDT service channel field	MDT SVC #1	OCTET[6]	
	MDT SVC #2	OCTET[6]	
	...		(And so on for slaves#3 to #(N-1).)
	MDT SVC #N	OCTET[6]	

Table 17 – MDT SVC (for each slave)

DLPDU part	Data Field	Data Type	Value/Description
MDT SVC #k	SVC control	OCTET[2]	
	SVC INFO	OCTET[4]	

5.5.7.3.2 SVC control

The content of service channel (SVC) control word shall be as specified in Table 18.

Table 18 – SVC control word (DLL)

Bit No.	Value	Control word description
31-20		Reserved
19-18		Configuration bits
	00	Reserved
	01	Loopback on P2
	10	Forwarding P1-->P2
	11	P2 Tx off
17-16		Loopback bit
	00	Reserved
	01	Loopback on P1
	10	Forwarding P2-->P1
	11	P1 Tx off
15-11		Reserved for application profile (e.g. IEC 61800-7-20x)
10		Reserved for application layer (IEC 61158-6)
9-8		Reserved for application profile (e.g. IEC 61800-7-20x)
7-6		Reserved for application layer (IEC 61158-6)
5-3		Data block element
	000	Service channel not active, close service channel or break a transmission in progress
	001	IDN of the operation data. The service channel is closed for the previous IDN and opened for a new IDN
	010	Name of operation data
	011	Attribute of operation data
	100	Unit of the operation data
	101	Minimum input value
	110	Maximum input value
	111	Operation data
2		Bit last transmission
	0	Transmission in progress
	1	Last transmission
1		R/W (read/write)
	0	Read service INFO
	1	Write service INFO
0		MHS (master handshake bit)
	toggle	Service transport handshake of the master

5.5.7.3.3 SVC INFO

The structure of SVC INFO shall be as specified for Type 16 control word (see IEC 61158-4-16, 4.4.1.3).

Exception: As compared to Type 16, SVC INFO shall always be 4 OCTET long. If only 2 OCTETs are transmitted in a step, then the value shall be in the low word, and the high word value shall be "don't care".

5.5.7.4 MDT real-time data field

5.5.7.4.1 General

The MDT real-time data field (see Table 19) shall contain all real-time data of the configured devices. Each device shall have its own real-time data field as specified in Table 20. The master real-time data to any one device shall not be spread into two different MST data telegrams.

Table 19 – MDT real-time data field

DLPDU part	Data Field	Data Type	Value/Description
MDT real-time data field	Real-time data slave #1	OCTET[see Table 20]	
	Real-time data slave #2	OCTET[see Table 20]	
	...		(And so on for slaves #3 to #(N-1))
	Real-time data slave #N	OCTET[see Table 20]	

Table 20 – MDT real-time data (for each device)

DLPDU part	Data Field	Data Type	Value/Description
Real-time data #k	Device control	OCTET[4]	
	Configurable real-time data	OCTET[see 5.5.7.4.3]	

5.5.7.4.2 Device control

The content of device control field shall be as specified in Table 21.

Table 21 – Device control field

Bit No.	Value	Description
31-16		Reserved
15-6		Reserved for application profile (e.g. IEC61800-7-20x)
5-1		Reserved
0		Changing topology bit
	toggle	Toggles if master commands to change the topology

5.5.7.4.3 Configurable MDT real-time data

The configurable real-time data field of the MDT shall be as specified in IEC 61158-4-16, 4.4.3.

5.6 AT DLPDU

5.6.1 AT MST field summary

The AT is a Type 19 telegram and shall be as specified in Table 22, whereas the Type 19 header is called AT MST header.

Table 22 – AT MST header

DLPDU part	Data Field	Data Type	Value/Description
AT MST header	AT type	OCTET[1]	
	AT phase	OCTET[1]	
	AT CRC	OCTET[4]	

5.6.2 Evaluation of AT in the slaves

The AT MST shall be generated by the master and evaluated by the slaves. Each slave shall evaluate the AT MST according to Table 23.

Table 23 – AT MST fields to be considered by the slave

	AT type	AT Phase	AT CRC
AT0	Yes	No	No
AT1	Yes	No	No
AT2	Yes	No	No
AT3	Yes	No	No

5.6.3 AT type

Refer to 5.4.2, whereas bit #6 shall be 1.

5.6.4 AT Phase

The AT phase shall contain the status of the Type 19 communication during initialization and during normal operation. The phase shall be generated by the master and transmitted in every AT. The structure is the same as for MDT phase (see 5.5.4).

The phase of an AT shall not be evaluated by the slave (see Table 23).

5.6.5 AT CRC

The AT CRC shall be generated by the master as the MDT CRC (see 5.5.5).

The AT CRC shall not be evaluated by the slave (see Table 23).

5.6.6 AT Payload during initialization

5.6.6.1 General

The content of the AT payload depends on the communication phase (CP) as described in the following subclauses.

5.6.6.2 CP0

The master shall always transmit AT0 telegrams, and no AT1, AT2, nor AT3 telegrams. AT0 shall be structured as stated in Table 24.

Table 24 – AT0 structure in CP0

DLPDU part	Data Field	Data Type	Value/Description
AT MST	Type 19 AT0	OCTET[1]	
	AT phase	OCTET[1]	CP0
	AT CRC	OCTET[4]	
AT payload	Device address #0	OCTET[2]	
	...		Device address #1..254
	Device address #255	OCTET[2]	

5.6.6.3 CP1 and CP2

In CP1 and CP2, the master shall always transmit AT0 and AT1 telegrams, but no AT2, nor AT3 telegrams.

A AT data field of the AT0 shall contain the service channel (see 5.6.7.3) and the device status (see 5.6.7.4.3) of device addresses 0 to 127. The MDT data field of the MDT1 shall contain the service channel and the device status of device addresses 128 to 255. See Table 25 and Table 26.

The slave shall respond by setting the handshake bit (AHS) and valid bit (SVC valid) to 1 in the corresponding SVC status. The SVC INFO shall be "don't care"; the shut-down bit shall be active in the device status. The bits "ready to operate" (bits 15 and 14) shall be set to 0.

Table 25 – AT0 in CP1 and CP2

DLPDU part	Data Field	Data Type	Value/Description
AT MST	Type 19 AT0	OCTET[1]	
	Phase 1 or 2	OCTET[1]	
	AT phase	OCTET[1]	CP1 or CP2
AT data field	AT CRC	OCTET[4]	
	Device #0 SVC INFO	OCTET[4]	
	...		(And so on for devices #1 to #126)
	Device #127 service status	OCTET[2]	
	Device #127 SVC INFO	OCTET[4]	
	Device #0 device status	OCTET[4]	
	...		(And so on for devices #1 to #126)
	Device #127 device status	OCTET[4]	

Table 26 – AT1 in CP1 and CP2

DLPDU part	Data Field	Data Type	Value/Description
AT MST	Type 19 AT1	OCTET[1]	
	Phase 1 or 2	OCTET[1]	
	AT phase	OCTET[1]	CP1 or CP2
AT data field	Device #128 service status	OCTET[2]	
	Device #128 SVC INFO	OCTET[4]	
	...		Device #129..#254 service status
	Device #255 service status	OCTET[2]	
	Device #255 SVC INFO	OCTET[4]	
	Device #128 device status	OCTET[4]	
	...		Device #129..#254 device status
	Device #255 device status	OCTET[4]	

5.6.6.4 CP3 and CP4

In CP3 and CP4, the master and the slaves shall transmit ATs as in normal operation (see 5.6.7).

In CP3 only the service channel and the device status shall be used. The configurable real-time data of the AT do not matter, but they shall have the number of OCTETs required for CP4 and normal operation. The positions of the service channels and the real-time data fields in the AT relevant to the individual slaves shall be as transmitted by the master to the slaves during CP2 with the corresponding communication parameters.

In CP4 the configurable real-time data shall be valid and filled with actual values as determined by the parameters that the master transmitted to the slaves during CP2. The device status that depends on the application profile is valid. The bits "Device ready to operate2 (15 and 14) shall be set to 01. Further combinations shall be as specified in the application profiles.

In the device status the shut-down bit and the procedure command change bit shall be active. The bits "Device ready to operate" (bits 15 and 14) shall be set to 0. Depending on the application profile some bits in the device status may be valid starting in CP3 and up to CP4.

5.6.7 AT payload in normal operation

5.6.7.1 Introduction

The AT payload structure shall be as specified in Table 27.

Table 27 – AT data field

DLPDU part	Data Field	Data Type	Value/Description
AT data field	AT hot-plug field	OCTET[8]	See 5.5.7.2
	AT service channel field	OCTET[See 5.6.7.3]	Optional. See Figure 1
	AT real-time data field	OCTET[See 5.6.7.4]	Optional. See Figure 1

For each slave, IDN S-0-1014 shall set the offset for its service channel. S-0-1011 shall set the offset for the real-time data field. S-0-1012 shall define the length of the AT (see Figure 3). These parameters shall be transmitted from the master to the slaves in CP2 during initialization.

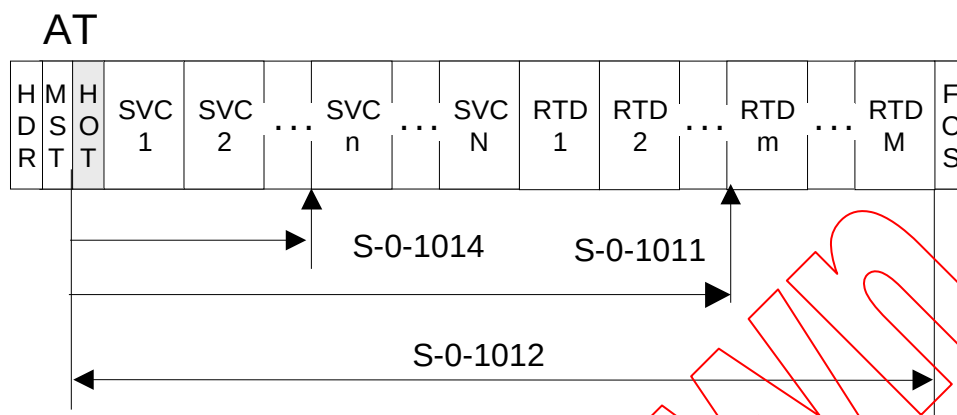


Figure 3 – Offsets within AT payload

5.6.7.2 AT hot-plug field

5.6.7.2.1 AT hot-plug field summary

The structure of the AT hot-plug field shall be as specified in Table 28 or in Table 29, depending upon hot-plug phase (HP0, HP1, HP2, see 6.3).

Table 28 – AT hot-plug field in HP0 and HP1

DLPDU part	Data Field	Data Type	Value/Description
AT hot-plug field	Device address	OCTET[2]	
	HP status	OCTET[2]	
	HP INFO	OCTET[4]	

Table 29 – AT hot-plug field in HP2

DLPDU part	Data Field	Data Type	Value/Description
AT hot-plug field	Device address	OCTET[2]	
	SVC status	OCTET[2]	
	SVC INFO	OCTET[4]	

5.6.7.2.2 Device address field

See 5.5.7.2.2.

5.6.7.2.3 HP status field (in HP0 and HP1)

The content of HP control field shall be as specified in Table 30.

Table 30 – HP status field (in HP0 and HP1)

Bit No.	Value	Description
16-31		Reserved
15-12		Reserved
11		Error flag
	0	No error in HP1
	1	Error in HP1 (error code bit 5-0)
10		HP field vs. SVC communication
	0	HP field is active
	1	SVC is active (HP is finished)
9-8		Slave HP information
	00	Slave in HP0 (S&F)
	01	All HP0-Parameter received (FF&LB)
	10	Slave in HP1 (acknowledge bit 5-0)
	11	Reserved
7-6		Reserved
5-0		HP function and error codes
	10 0000	Reserved
	10 0001	MDT-SVC pointer received without error
	10 0010	MDT-RTD pointer received without error
	10 0011	AT-SVC pointer received without error
	00 0100	AT-RTD pointer received without error
	10 0101 – 11 1111	Reserved
	00 0000	Reserved
	00 0001	Error: Next HP slave has same device address
	00 0010 – 00 0011	Reserved

5.6.7.2.4 HP INFO fields (in HP0 and HP1)

Refer to the AT service channel field as described in 5.6.7.3.3.

5.6.7.2.5 Hot-plug SVC status field (in HP2)

Refer to the AT SVC status field as described in 5.6.7.3.2.

5.6.7.2.6 Hot-plug SVC INFO field (in HP2)

Refer to the AT service channel field as described in 5.6.7.3.3.

5.6.7.3 AT service channel SVC field**5.6.7.3.1 AT service channel fields summary**

The AT service channel field (see Table 31) shall contain all service channels (SVC) of the configured devices within a Type 19 network. Each device shall have its own dedicated service channel. The service channel for each device shall be as specified in Table 32.

Table 31 – AT service channel field

DLPDU part	Data Field	Data Type	Value/Description
AT service channel field	AT SVC #1	OCTET[6]	
	AT SVC #2	OCTET[6]	
	...		(And so on for slaves#3 to #(N-1))
	AT SVC #N	OCTET[6]	

Table 32 – AT SVC (for each slave)

DLPDU part	Data Field	Data Type	Value/Description
AT SVC #k	SVC status	OCTET[2]	
	SVC INFO	OCTET[4]	

5.6.7.3.2 SVC status

The structure of SVC status shall be as specified in Table 33.

Table 33 – AT SVC status description (DLL)

Bit No.	Value	Description
31-20		Reserved
25		S III S-telegram on P2
	0	No
	1	Yes
24		S III P-telegram on P2
	0	No
	1	Yes
23		LINK on P2
	0	No
	1	Yes
22		S III S-telegram on P1
	0	No
	1	Yes
21		S III P-telegram on P1
	0	No
	1	Yes
20		LINK on P1
	0	No
	1	Yes
19-18		
	00	Reserved
	01	Loopback on P2
	10	Forwarding P1-->P2
	11	P2 Tx off
17-16		
	00	Reserved

Bit No.	Value	Description
	01	Loopback on P1
	10	Forwarding P2-->P1
	11	P1 Tx off
15-8		Reserved for the application profile (e.g., IEC 61800-7-20x)
7-6		Reserved for application layer (IEC 61158-5)
5		Procedure command change bit
	0	No change in procedure command acknowledgement
	1	Changing procedure command acknowledgment
4		Reserved
3		Status command value processing
	0	Drive ignores the command values (e.g., during Halt drive, drive controlled functions or programmed delay times)
	1	Drive follows the command values
2		SVC error
	0	No error
	1	Error in SVC, error message in SVC INFO
1		Busy
	0	Step finished, slave ready for new step
	1	Step in process, new step not allowed
0		AHS
	toggle	SVC transport handshake of the slave (toggle bit)

5.6.7.3.3 SVC INFO

The structure of service channel (SVC) INFO shall be as specified for Type 16 control word (see IEC 61158-4-16, Table 7).

Exception: As compared to Type 16, SVC INFO shall always be 4 OCTET long. If only 2 OCTETs are transmitted in a step, then the value shall be in the low word, and the high word value shall be "don't care".

5.6.7.4 AT real-time data field

5.6.7.4.1 General

The configurable real-time data field of the AT (see Table 34) shall contain all real-time data that the devices transmit to the master (MS data).

As an option, it shall contain in addition the real-time data for CC communication (CC data). The position of this data in the telegram shall be behind the MS data of all slaves.

In a Type 19 network, in which this option is used, each device may be configured depending on the application for transmitting its MS data field only, or both its MS and its CC data fields.

Table 34 – AT real-time data field

DLPDU part	Data Field	Data Type	Value/Description
AT real-time data field	MS data field		
	CC data field		

5.6.7.4.2 AT MS data field description

The AT MS data field (see Table 35) shall contain all MS data of the configured devices. Each configured device shall have its own MS data field as specified in Table 36. One slave's MS data shall not be spread into two different AT data telegrams.

Table 35 – AT MS data field

DLPDU part	Data Field	Data Type	Value/Description
AT MS data field	MS data device #1		
	...		(And so on for slaves#3 to #(N-1).)
	MS data device #N		

Table 36 – AT MS data (for each device)

DLPDU part	Data Field	Data Type	Value/Description
MS data field #k	Device status	OCTET[4]	
	Configurable MS data	OCTET[see 5.6.7.4.4]	

5.6.7.4.3 Device status

The content of device status field shall be as specified in Table 37

Table 37 – Device status field

Bit No.	Value	Description
31-16		Reserved
15-8		Reserved for the application profile (e.g., IEC 61800-7-20x)
7-6		Reserved for application layer (IEC 61158-5)
5		Procedure command change bit
	0	No change in procedure command acknowledgement
	1	Changing procedure command acknowledgment
4		Reserved
3		Status command value processing
	0	Device ignores the command values
3	1	Drive follows the command values
2		SVC error
	0	No error
	1	Error in SVC, error message in SVC INFO
1		Busy
	0	Step finished, slave ready for new step
	1	Step in process, new step not allowed
0		Changing topology bit
	toggle	Toggles if slave has changed the topology

5.6.7.4.4 Configured AT MS data

The configurable MS data field of the AT shall be as specified in IEC 61158-4-16, 4.4.3.

If a device within a Type 19 network transmits its real-time data using only CC communication, its configured AT MS data field shall be empty (0 OCTET). Its AT MS data field consists of its device status word only.

5.6.7.4.5 AT CC data field description

The AT CC data field (see Table 38) shall contain all CC data of the configured devices. Each configured device shall have its dedicated AT CC data field producer as specified in Table 39. One producer's CC data shall not be spread into two different AT data telegrams.

Table 38 – CC data field

DLPDU part	Data Field	Data Type	Value/Description
CC data field	CC data field producer device #1		
	...		(And so on for slaves #3 to #(N-1))
	CC data field producer device #N		

Table 39 – CC data field producer

DLPDU part	Data Field	Data Type	Value/Description
CC data field producer #k	CC consumer control	OCTET[2]	
	Configured CC data	OCTET[see 5.6.7.4.7]	

5.6.7.4.6 CC consumer control

The CC consumer control shall be set as specified in Table 40.

Table 40 – CC consumer control

Bit No.	Value	Description
0		CC data field delay
	0	CC data field on direct way, i.e. in time
	1	CC data field mirrored in the master, i.e. delayed by one Type 19 communication cycle
1-3		Reserved
4		CC data field validity
	0	CC data field invalid
	1	CC data field valid
5-9		Reserved
10		CC sync (IPO)
	toggle	CC sync (IPO) toggles according to the producer cycle time $t_{P_{Cyc}}$
11-13		Reserved
14		Producer readiness
	0	Producer not ready
	1	Producer ready
15		Reserved

5.6.7.4.7 Configured AT CC-data field

The configurable MS data field of the AT shall be as specified in IEC 61158-4-16, 4.4.3.

6 DL management

6.1 Overview

DL-management procedures are functionally processed in response to DL-management service requests submitted by the DL-user and events caused by the network.

6.2 Enable and disable cyclic communication

6.2.1 Introduction

Upon an `Initiate_cyclic_communication` (ICC) request by the DL user in the master device the so-called phase upshift is initiated.

A `Notify_cyclic_communication` (NCC) indication is generated for the DL user in the slave device if the phase upshift has been successfully completed.

Upon a `Disable_cyclic_communication` (DCC) request by the DL user in the master device the so-called phase downshift is initiated.

A `Notify_cyclic_communication_disabled` (NCCD) indication is generated for the DL user in the slave device if the cyclic communication has been disabled.

A `Notify_error` (NER) indication is generated for the DL user in a master and a slave device if an error has occurred in the cyclic communication.

6.2.2 Communication phases (CP)

Initialization shall be divided into six communication phases (NRT and 5 CPs):

- After a station has been powered up, and internal checks are completed and error-free, it shall operate in non real-time (NRT) mode (see 4.2.1.1).
- initialization of a Type 19 network shall always begin with CP0;
- CP0 shall be used for recognizing the participating devices;
- CP1 shall be used to configure the slave devices for acyclic communication;
- CP2 shall be used to configure the slave devices for cyclic communication and for parameter setting in the device via acyclic communication;
- CP3 shall be used to further configure the slave devices, the cyclic communication shall already be running but shall not be used;
- In CP4 the initialization process is complete and the Type 19 network shall be in normal operation.

It shall also be possible to enter CP0 from any higher phase. It shall not be possible to enter other phases except when leaving the previous one in ascending order.

The master shall initiate a specific CP by setting the MDT phase OCTET in the Type 19 DLPDUs (see 5.5.4). The slaves shall follow accordingly. Only in the case of a communication error shall the slaves switch to CP0.

The initialization procedure is shown in Figure 4.

NOTE The hot-plug procedure which is part of Figure 4 is described in 6.3.

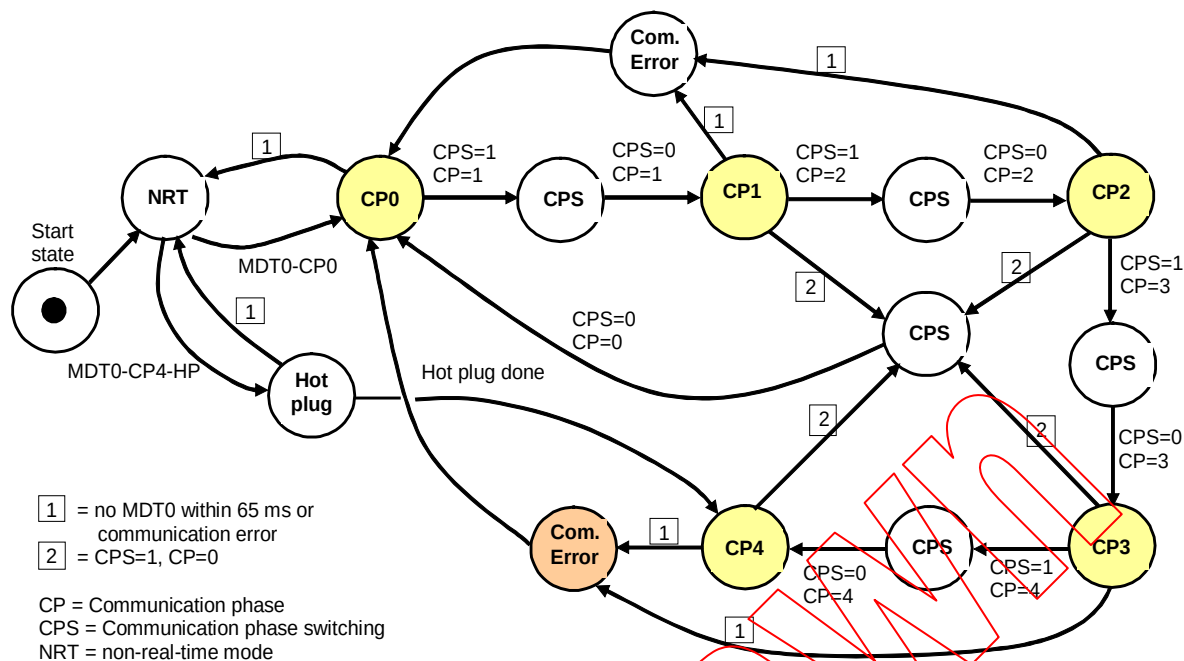


Figure 4 – Communication phase transitions

The slaves shall follow accordingly, except in following cases:

- in case of a communication error the slaves shall switch to CP0;
- if a slave is connected to an already operational network and thus receive an MDT0 that indicates CP4, it shall enter the hot-plug procedure (see 6.3).

6.2.2.1 Non-real-time mode (NRT)

In the NRT mode the device shall behave as a store-and-forward switch. Standard Ethernet communication shall be active, if the device supports it.

If the slave receives an MDT0 with CP0 while it is in NRT mode the sending of a Standard Ethernet telegram shall be cancelled immediately and the MDT0 shall be sent instead. After this, the slave shall activate CP0 as well as the loopback at the port at which the slave has received the MDT0.

6.2.2.2 Communication phase 0 (CP0)

6.2.2.2.1 General

In CP0 the service channel shall not be active, but the optional NR channel shall be active.

Slaves with device address ADR = 0 shall support CP0 in the same way as slaves with ADR > 0.

During CP0, the master shall send MDT0 and AT0 as specified in clause 0 on one or both of its ports, depending on the given topology, in order to

- check the wiring (e.g., the network is closed);
- check all present slaves in the received AT0 (device address 0 to 255);
- measure the ring delays (P-Channel and/or S-Channel) for synchronization purposes.

The master shall transmit the AT0 and set the content to 0.

The slave shall read and increment the content of corresponding device address field in the AT. At the end of CP0 the AT data field shall contain the number of devices that reacted to each device address. The slave shall process AT0-P on the P-Channel and AT0-S on the S-Channel only, once per communication cycle. The slave shall not process an AT0-P on the S-Channel and vice versa.

If the slave does not receive any MDT0 on the other port the loopback shall be activated without error message. The loopback shall be re-opened if an MDT0 is received on the other port.

6.2.2.2.2 Leaving CP0

The master shall wait for its MDT0 and AT0 to be received. Depending on its configuration, the master may compare the detected device addresses with the device addresses that it is expecting to find, and then evaluate deviations (e.g., generate an error message). As soon as the master has received 100 AT0 with the same content, the master shall initiate to switch to CP1 (see 6.2.2.7).

If this procedure cannot be achieved within the time set by the master, the master shall remain in CP0 and generate a message. The scope of the message and at what point it has to be activated is a function of the master.

If CP0 is initiated as a response to a previous communication error, a routine in the master may be used to cause an automatic advance routine to CP2 with the possibility of error diagnostics, as specified by its manufacturer or depending upon configuration.

If a slave does not receive any MDT0 while it is in CP0 within the time window of 65 ms, it shall switch to the NRT mode.

6.2.2.3 Communication phase 1 (CP1)

6.2.2.3.1 General

CP1 shall be used to determine which slaves will be activated in CP2 to CP4. Slaves, the device address of which is $ADR \neq 0$ shall no longer respond to the telegrams during phases CP1 and CP2 other than to forward the telegrams. Slaves that are not being addressed in CP1 and whose address is not 0 shall behave like slaves with the device address 0. No slave shall react in CP1 if address 0 or 255 is queried.

In CP1 the service channel shall be initialized. If available, the optional NR channel shall be active.

The master shall send MDT0 and MDT1 to request the corresponding slave to insert data into AT0 or AT1. AT0 and AT1 shall be transmitted by the master with an allocated AT data field (contents is 0). The master shall not send the MDT1 and AT1, if the time t_6 (beginning of NR channel) is exceeded by AT1 (e.g., jitter too large) or if the master supports device addresses 1 to 127 only.

A requested slave shall insert the response into the corresponding AT service channel.

A device address may have to be queried several times depending upon its configuration. The master shall repeat its request until the addressed slave acknowledges or until the timeout has elapsed.

If a slave does not respond, the master may address it again depending upon configuration. This request procedure shall be repeated until the identification time has elapsed. The identification time is defined by the master.

6.2.2.3.2 Leaving CP1

After the master has identified the slaves on the network, the master shall initiate to switch to CP2 (see 6.2.2.7).

If the identification time is exceeded or deviations to the stored device addresses are detected, the initialization shall not be continued. The master may respond with an error message depending upon configuration.

If a slave does not receive any MDT0 in CP1 within 65 ms it shall switch to CP0.

6.2.2.4 Communication phase 2 (CP2)

6.2.2.4.1 General

During CP2, the slaves shall be addressed specifically using their corresponding service channel. For CP2 and higher phases, they shall support complete service channel functionality. The optional NR channel shall be active if available.

As a minimum, the communication parameters required for CP3 and CP4 and the parameters for determining the length and contents of the MDTs and ATs shall be transmitted to the slaves. The slave shall show in "IDN-list of operation data for CP2" which data shall be transferred during CP2 (see S-0-0018).

The master shall transmit the network delays to all slaves for synchronization purposes. The slaves shall adjust the synchronization time depending on the network delays. The master may determine the physical order of the slaves depending upon configuration.

The entire information exchange takes place via the mechanisms of the service channel (see 7.2). The reliability of transmission shall be guaranteed by the MHS and AHS bits as well as the HS timeout. Further parameter exchanges can take place in CP2 or CP3. No slave shall react in CP2 if the device addresses 0 or 255 are queried. If a slave is not requested in CP1, then it shall not react to a request in CP2.

6.2.2.4.2 Leaving CP2

The transition from CP2 to CP3 shall be performed according to the same procedure as for Type 16 (see IEC 61158-4-16, 5.2.2.5.2).

Exception: The master shall not switch directly to CP3. It shall instead initiate to switch to CP3 (see 6.2.2.7).

If a slave does not receive any MDT0 in CP2 within 65 ms it shall switch to CP0.

6.2.2.5 Communication phase 3 (CP3)

6.2.2.5.1 General

Starting with CP3, the exchange of data shall be done via the telegrams defined for CP4. The master shall send the configured MDTs and ATs to all slaves.

During CP3, the parameters for the slaves shall be set by means of the service channel. The slave shall show in "IDN-list of operation data for CP3" which data in CP3 needs to be transferred (see S-0-0019). Transmission reliability for the service channel shall be guaranteed by the MHS and AHS-bits as well as the HS timeout.

The optional NR channel shall be active if available. If the master sets $t_6 = t_7 = 0$ the NR channel is deactivated in CP3 and CP4.

All bits in the device control and device statuses that are dependent of the application profile shall be set to 0 during communication phases CP0 to CP2. In CP3, the application profile shall be activated.

6.2.2.5.2 Leaving CP3

The transition from CP3 to CP4 shall be performed according to the same procedure as for Type 16 (see IEC 61158-4-16, 5.2.2.6.2).

Exception: The master shall not switch directly to CP4. It shall instead initiate to switch to CP4 (see 6.2.2.7).

If a slave does not receive any MDT0 in CP3 within 65 ms it shall switch to CP0.

6.2.2.6 Communication phase 4 (CP4) – end of initialization

6.2.2.6.1 General

Upon switching to CP4 the initialization is complete.

6.2.2.6.2 Leaving communication phase 4 (CP4)

Leaving CP4 shall be the same as for Type 16 (see IEC 61158-4-16, 5.2.2.7.2).

6.2.2.7 Switching of communication phases (CPS)

6.2.2.7.1 Sequence of CP switching in the master

- a) In order to switch the communication phase, the master shall set the condition in the MDT MST (CPS = 1 and new CP value in phase field). The master shall determine the current CP, the current CP+1 or CP0 as the new CP.
- b) The master shall determine a time-out of 200 ms and waits until the slaves no longer write data to the ATs. For this purpose the master shall check the device address of all slaves to see if it is 0; and in CP1 to CP4 it shall also check the RT valid bit to see if it is 0.
 - 1) If the master still receives data from the slaves after the time-out (in CP0: device address $ADR \neq 0$, in CP1 to CP4: RT-Valid = 1), it shall produce an error message showing the respective device addresses. After deleting the error, the master shall interrupt the phase switch and switch to CP0.
 - 2) If the master receives a communication error in the slave's C1D (only possible in CP1 to CP4) during time-out, it shall display an error message, deactivate the time-out, and stay in the current CP in order to fix the error. If the error can be fixed the phase switching shall continue; if it cannot be fixed the master shall delete the error and switch to CP0.
- c) If the device address = 0 or RT valid = 0, the master shall stop the transmission of MDTs or ATs and prepare the new CP.
- d) Once all internal preparations are done, the master shall start sending MDTs and ATs again.
 - 1) The master shall set either the condition "phase switch completed with new CP" (CPS = 1 and new CP value in phase field) or switch back to CP0.
 - 2) The master shall set condition "phase switch to CP0" (Phase, CPS = 1 and CP0).
- e) The master again shall set a time-out of 200 ms and wait until all slaves restart writing data to ATs. The master shall therefore check each slave's device address in CP0 to see if it is $\neq 0$; and in CP1 to CP4, the RT valid bit to see if it is 1.
 - 1) If the master after the time-out does not receive any more data from the slaves (in CP0: device address $ADR = 0$, in CP1 to CP4: RT-Valid = 0), it shall display an error message showing the respective device addresses. After deleting the error the master shall switch to CP0.

- 2) If the condition (Device address $ADR \neq 0$ or $RT\text{-}Valid = 1$) is true, the new CP shall be active and the switching is complete.

6.2.2.7.2 Sequence of CP switching in the slave

- a) The slave shall recognize the phase switch in the MDT0 (Phase, Bit CPS = 1 and new CP) and check if the new CP is valid. The RT data in the MDTs shall be disregarded.
 - 1) If the CP is valid the slave shall not write RT data to the ATs any more and wait until it does not receive MDT0 any more. After that the slave shall set a new time-out of 500 ms and prepare the new CP internally.
 - 2) If the CP is invalid the slave shall generate a communication error in C1D and sends it to the master. The slave shall stay in the same CP.
- b) After the master sends no MDT0 the slaves shall wait for another MDT0.
 - 1) If the slave after the time-out does not receive MDT0 from the master it shall store the error and may display it (e.g., LED); after that it shall switch to CP0.
 - 2) If the slave receives the MDT0 with a valid condition (Phase, CPS = 0, and CP = OK), then the new CP shall be active and the switching is complete. The slave shall restart evaluating the RT data in the MDT and write data to the AT.
 - If the slave receives an MDT0 with the condition (Phase, CPS = 1, CP = OK), it shall wait for the valid condition.
 - If the slave receives an MDT0 with the condition (Phase, CPS = 1 and CP0), it shall activate the phase switch once more.
 - If the slave receives an MDT0 with invalid condition (CP is not OK), it shall store the error and display it on the device (e.g., LED). The slave shall then switches to CP0.

6.3 Hot-plug procedure

6.3.1 Introduction

Upon an Enable_Hotplug (EHP) request by the DL user in the master device a list of expected devices that may be hot-plugged (depending on the application) is passed to the DL.

Hot-plugging is only possible in communication phase CP4 (normal operation).

The DL user is informed by a Notify_Device_Status_Change (NDSC) if a new device has been hot-plugged.

The last slave in a line configuration shall monitor continuously its unused port and, if an additional device gets connected, it shall forward all received telegrams to this new device.

The additional device shall start in the NRT mode ("store and forward") as described in 6.2.2.1. If the additional device supports the Type 19 protocol, it shall send the real-time telegrams (MDTs and ATs) back. Using the hot-plug fields in MDTs and ATs, the master and the additional device shall be able to communicate. After processing through the hot-plug procedure, the additional device shall become the last slave within the line configuration.

Running up a slave device into CP4 shall be achieved using a specific procedure, which is divided in 3 phases (HP0, HP1, HP2).

6.3.2 Hot-plug phase HP0

In HP0 the master shall transmit to the hot-plugging device the following basic parameters that are common to all devices, without acknowledgment (MHP-ADR = 0xFF):

- communication cycle time (t_{Scyc}) (IDN S-0-1002);
- AT transmission starting time (t_1) (IDN S-0-1006);

- NRC transmission time (t_6 and t_7)(IDN S-0-1017);
- lengths of MDTs (IDN S-0-1010);
- lengths of ATs (IDN S-0-1012).

As soon as the hot-plugging device has received these parameters, it shall switch to loopback at the port at which it has received the MDT0s.

6.3.3 Hot-plug phase HP1

In HP1 the master shall transmit to the hot-plugging device the following device-specific parameters, with acknowledgment (MHP-ADR = device address), using the hot-plug fields in MDTs and ATs:

- SVC offset in MDT (IDN S-0-1013);
- SVC offset in AT (IDN S-0-1014);
- RTD offset in MDT (IDN S-0-1009);
- RTD offset in AT (IDN S-0-1011).

The master shall then activate the SVC (service channel) by setting bit 10 in the HP control within the MDT hot-plug field. The hot-plugging device acknowledges by setting bit 10 in the SVC status within the AT hot-plug field.

6.3.4 Hot-plug phase HP2

In HP2 the master shall fully configure the hot-plugging device using SVC (service channel) as in CP2 (see 6.2.2.4).

It shall then initiate hot-plugging device switching to normal operation (CP4) using IDN-S-0-0423. The hot-plugging device shall perform the check procedures as described in 6.2.2.4.2 and 6.2.2.5.2.

At the end of this procedure, the hot-plugging device shall be in normal operation (CP4).

6.4 Status procedures

Upon a Get_Device_Status (GDS) request by the DL user in the master device the status word of the specified device is returned to the DL user.

Upon a Set_Device_Status (GDS) request by the DL user in the master device the control word of the specified device is set.

Upon a Get_Network_Status (GNS) request by the DL user in the master device the status of the network is returned to the DL user.

7 Data transmission methods

7.1 Overview

Data transmission methods are the means by which a DLE performs its functions and affects the behavior of the DL-protocol. Methods are initiated, executed and terminated under the control of invoked services, as specified in the Type 19 DL-service.

7.2 SVC

7.2.1 Introduction

Acyclic data is exchanged between a master and a slave device upon a Read (RD) request initiated by the DL user in a master device.

Type 19 service channel (SVC) shall be as specified for Type 16 (see IEC 61158-4-16, 6.2), with the following exceptions:

- the service channel shall be initialized during CP2 (and not in CP1 as in Type 16);
- the number of data OCTETs is fixed as always being 4 OCTETs.

7.3 RTC

7.3.1 Introduction

Cyclic data is exchanged between all devices in a Type 19 network in communication phase CP4 according to the configuration given by the Initiate_cyclic_communication request (see 4.2).

7.3.2 Read_Cyclic (RDC)

Cyclic data is read by a DL user using the Read_Cyclic (RDC) request.

7.3.3 Write (WRC)

Cyclic data is written by a DL user using the Write_Cyclic (WRC) request. The cyclic data is transmitted in the next communication cycle of the Type 19 network.

7.3.4 Notify_Cyclic_Data (NCD)

Upon reception of a DLPDU of Type MDT0-MST the DL generates a Notify_Cyclic_Data (NCD) indication for the DL user.

8 Telegram timing and DLPDU handling

8.1 Usage of real-time channel with different network topologies

8.1.1 Introduction

The topology consists of full-duplex, point-to-point transmission lines and participants. The master and the slaves are parts of the network and are its participants.

Each participant has two communication ports (port 1 and port 2). Port 1 (P1) and port 2 (P2) shall be interchangeable.

The topology shall be either a ring structure or a line structure. A ring shall have two logical channels and a line shall have only one logical channel.

The difference between ring and line structure is that the ring has a built-in redundancy against transmission media faults (e.g., cable break) and should be therefore preferred.

Each master handles only one network.

NOTE A control unit may have one or more master interfaces depending on the configuration.

Slave interfaces shall be used to connect the devices to the network. At the physical layer, a slave represents the connection of one or more devices to the network. Logically one slave

with several devices shall act the same as several slaves with one device each. The slaves are physically connected to each other participants through the network. Communication takes place between the master and the slaves; cross communication between the slaves is also supported.

The physical arrangement of slaves in the network shall be independent from the predefined device addresses ADR for the slaves, as well as from the sequence of the real-time data fields in the MDT and AT (see 5.5.7.4, 5.6.7.4.2, and 5.6.7.4.5).

Any slave shall be able to recognize the topology at any time, using the difference between primary and secondary telegrams. This is important when a slave is added to the communication at a later point in time (e.g., addition of new machine parts, hot-plug). If a slave receives telegrams with the same Type 19 type on both ports (MDT0-P or MDT0-S) it shall recognize a line. If it receives an MDT0-P on one port and an MDT0-S on the other port, it shall recognize a ring.

8.1.2 Ring structure

The ring structure shall consist of a primary and a secondary channel. All slaves shall work in forwarding mode. Redundancy to protect against cable fault (e.g., disconnection, undesired cable break) is achieved through this ring. It shall also be possible to open the ring and insert/remove slaves during operation (hot-plug).

8.1.3 Line structure

The line structure shall consist of either a primary or a secondary channel, depending upon configuration. The last physical slave shall perform the loopback function. All other slaves shall work in forwarding mode. It shall also be possible to add and remove slaves at the end of the line during operation (hot-plug). The ports which are not used for Type 19 communication shall support any Ethernet-based communication. The master may communicate with 2 sets of Type 19 slaves using two lines.

8.2 Communication mechanisms

8.2.1 General

Master and slave shall have the same hardware properties. Each port shall be assigned to a processing unit and a multiplexer (see Figure 5). The functions in the master and the slave shall depend on the topology and on the time slot within the communication cycle (RT channel or NR channel, see Figure 6).

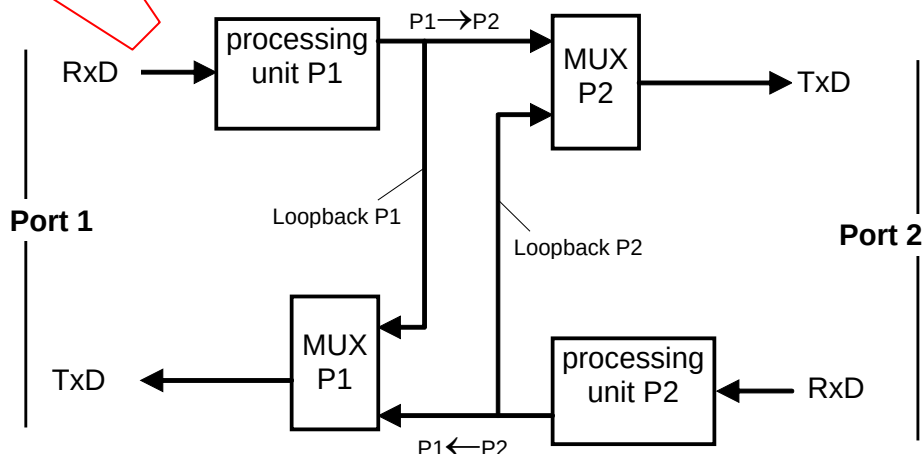


Figure 5 – Block diagram of master and slave