BS EN 61158-4-22:2014

BSI Standards Publication

Industrial communication networks — Fieldbus specifications

Part 4-22: Data-link layer protocol specification — Type 22 elements

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National foreword

This British Standard is the UK implementation of EN 61158-4-22:2014. It is identical to IEC 61158-4-22:2014. It supersedes BS EN 61158-4-22:2012 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AMT/7, Industrial communications: process measurement and control, including fieldbus.

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This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Foreword

The text of document 65C/762/FDIS, future edition 2 of IEC 61158-4-22, prepared by SC 65C "Industrial networks", of IEC/TC 65 "Industrial process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61158-4-22:2014.

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• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-09-19

This document supersedes EN 61158-4-22:2012.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association.

Endorsement notice

The text of the International Standard IEC 61158-4-22:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for bibliography, the following notes have to be added for the standards indicated:

IEC 61158-1	NOTE	Harmonised as EN 61158-1
IEC 61784-1	NOTE	Harmonised as EN 61784-1
IEC 61784-2	NOTE	Harmonised as EN 61784-2

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 61158-3-22	2014	Industrial communication networks - Fieldbus specifications Part 3-22: Data-link layer service definition - Type 22 elements	EN 61158-3-22	2014
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	-	-
IEEE 802.1D	-	IEEE Standard for local and metropolitan area networks - Media Access Control (MAC) Bridges	-	-
IEEE 802.1Q	-	IEEE Standard for Local and metropolitan area networks - Media Access Control (MAC) Bridges and Virtual Bridges	-	-
IETF RFC 768	-	User Datagram Protocol	-	-
IETF RFC 791	-	Internet Protocol - DARPA Internet Program Protocol Specification	-	-

CONTENTS

INTRODUCTION 7
1 Scope 9
1.1 General 9
1.2 Specifications 9
1.3 Procedures 9
1.4 Applicability 9
1.5 Conformance 10
2 Normative references 10
3 Terms, definitions, symbols, abbreviations and conventions 10
3.1 Reference model terms and definitions 11
3.2 Service convention terms and definitions 12
3.3 Common terms and definitions 13
3.4 Additional Type 22 definitions 14
3.5 Common symbols and abbreviations 17
3.6 Additional Type 22 symbols and abbreviations 18
3.7 Conventions 20
4 Overview of the DL-protocol 21
4.1 Operating principle 21
4.2 Communication model 21
4.3 Topology 22
4.4 DLPDU processing 22
4.5 General communication mechanisms 23
4.6 Gateway 24
4.7 Interaction models 24
5 DLPDU structure 24
5.1 Overview 24
5.2 Data types and encoding rules 25
5.3 DLPDU identification 26
5.4 General DLPDU structure 27
5.5 Communication management DLPDUs 29
5.6 Cyclic data channel (CDC) DLPDUs 37
5.7 Cyclic data channel (CDC) DLPDU data 38
5.8 Message channel (MSC) DLPDUs 38
5.9 Message channel DLPDU data - MSC message transfer protocol (MSC-MTP) 40
5.10 Time synchronization 43
6 Telegram timing and DLPDU handling 45
6.1 Communication mechanism 45
6.2 Device synchronization 47
7 Type 22 protocol machines 47
7.1 RTFL device protocol machines 47
7.2 RTFN device protocol machines 59
7.3 Message channel – Message transfer protocol (MSC-MTP) 61
Bibliography 65

Figure 1 – DLPDU sequence ... 46
Figure 2 – Communication relationship RTFN device ... 46
Figure 3 – Overview RTFL device protocol machines ... 48
Figure 4 – Protocol machine send DLPDU procedure ... 49
Figure 5 – Protocol machine receive DLPDU procedure ... 49
Figure 6 – CDCL send cyclic data sequence ... 50
Figure 7 – CDCL receive cyclic data sequence ... 51
Figure 8 – MSCL send sequence ... 52
Figure 9 – MSCL receive sequence ... 53
Figure 10 – Network management protocol machine ... 54
Figure 11 – Net management sequence at system boot up ... 55
Figure 12 – Initialization sequence ordinary device ... 56
Figure 13 – PCS configuration sequence ... 57
Figure 14 – Delay measurement principle ... 58
Figure 15 – Overview RTFN device protocol machines ... 59
Figure 16 – CDCN connection setup and release ... 60
Figure 17 – CDCN unpulish data ... 61
Figure 18 – Segmentation sequence ... 62
Figure 19 – Expedited transfer sequence ... 62
Figure 20 – Toggling from expedited transfer to segmented transfer ... 63
Figure 21 – Segmentation sequence for broad- or multicast message without Acknowledgement ... 64

Table 1 – DLPDU element definition ... 20
Table 2 – Conventions for protocol machine description ... 21
Table 3 – Transfer syntax for bit sequences ... 25
Table 4 – Transfer syntax for data type Unsignedn ... 26
Table 5 – Transfer syntax for data type Signedn ... 26
Table 6 – Type 22 DLPDU inside an ISO/IEC 8802-3 ... 27
Table 7 – Type 22 DLPDU inside a VLAN tagged ISO/IEC 8802-3 DLPDU ... 27
Table 8 – Type 22 DLPDU inside an UDP DLPDU ... 28
Table 9 – General structure of a Type 22 DLPDU ... 28
Table 10 – DLPDU header structure ... 29
Table 11 – Network verification prepare DLPDU ... 29
Table 12 – Network verification environment DLPDU ... 29
Table 13 – Network verification information DLPDU ... 29
Table 14 – Network verification acknowledgement DLPDU ... 30
Table 15 – RTFN scan network request DLPDU ... 30
Table 16 – RTFN scan network response DLPDU ... 30
Table 17 – Identification data ... 30
Table 18 – Identification data v2 ... 31
Table 19 – PhyLinkPortX ... 32
Table 20 – RTF support ... 33

Table 21 – RTF2 support 33
Table 22 – UseDHCP 34
Table 23 – DeviceRole 34
Table 24 – RTFN connection management DLPDU 35
Table 25 – CDCN connection still alive DLPDU 35
Table 26 – ID data 35
Table 27 – RTFL control DLPDU 35
Table 28 – RTFL configuration DLPDU 36
Table 29 – RTFL configuration acknowledgement DLPDU 36
Table 30 – RTFL configuration 2 DLPDU 37
Table 31 – RTFL configuration acknowledgement 2 DLPDU 37
Table 32 – CDCL DLPDU 37
Table 33 – CDCN DLPDU 38
Table 34 – CDC DLPDU data arrangement 38
Table 35 – CDC DLPDU data 38
Table 36 – MSCL DLPDU 39
Table 37 – MSCL control 39
Table 38 – MSCN DLPDU 40
Table 39 – MSC-MTP frame structure 40
Table 40 – Address type 41
Table 41 – MSC-MTP Init structure 41
Table 42 – MSC-MTP Init_Fast structure 42
Table 43 – MSC-MTP Send structure 42
Table 44 – MSC-MTP Acknowledgement structure 42
Table 45 – MSC-MTP Abort structure 43
Table 46 – Data structure of a message 43
Table 47 – DelayMeasurement start encoding 43
Table 48 – DelayMeasurement read encoding 44
Table 49 – PCS configuration encoding 44
Table 50 – Time synchronization service request 44
Table 51 – Time synchronization service response 44

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 implementers and designers;

b) for use in the testing and procurement of equipment;

c) as part of an agreement for the admittance of systems into the open systems environment;

d) as a refinement to the understanding of time-critical communications within OSI.

This 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.

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

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning Type 22 elements and possibly other types:

WO-2006/069691 A1	[PI]	Control system with a plurality of spatially distributed stations and method for transmitting data in said control system
DE-10 2004 063 213 B4	[PI]	Steuerungssystem mit einer Vielzahl von räumlich verteilten Stationen sowie Verfahren zum Übertragen von Daten in einem solchen Steuerungssystem
EP-1 828 858 A1	[PI]	Control system with a plurality of spatially distributed stations and method for transmitting data in said control system
JP-4 848 469 B2	[PI]	Control system with a plurality of spatially distributed stations and method for transmitting data in said control system
CN-101 111 807	[PI]	Control system with a plurality of spatially distributed stations and method for transmitting data in said control system
US-8 144 718 B2	[PI]	Control system having a plurality of spatially distributed stations, and method for transmitting data in such a control system

IEC takes no position concerning the evidence, validity and scope of these patent rights.

The holders of these patent rights have assured IEC that they are willing to negotiate licenses either free of charge or under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holders of these patent rights is registered with IEC. Information may be obtained from:

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73760 Ostfildern
Germany

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those identified above. IEC shall not be held responsible for identifying any or all such patent rights.

ISO (www.iso.org/patents) and IEC (http://patents.iec.ch) maintain on-line data bases of patents relevant to their standards. Users are encouraged to consult the data bases for the most up to date information concerning patents.

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-22: Data-link layer protocol specification – Type 22 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 IEC 61158 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.

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

IEC 61158-3-22:2014, *Industrial communication networks – Fieldbus specifications – Part 3-22: Data-link layer service definition – Type 22 elements*

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*

IEEE 802.1D, *IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Bridges,* available at <http://www.ieee.org>

IEEE 802.1Q, *IEEE Standard for Local and metropolitan area networks: Media Access Control (MAC) Bridges for Local and metropolitan area networks – Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks;* available at <http://www.ieee.org>

IETF RFC 768, *User Datagram Protocol;* available at <http://www.ietf.org>

IETF RFC 791, *Internet Protocol;* available at <http://www.ietf.org>

3 Terms, definitions, symbols, abbreviations and conventions

For the purposes of this document, the following terms, definitions, symbols and abbreviations 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 acknowledgement [ISO/IEC 7498-1]

3.1.2 DL-address [ISO/IEC 7498-3]

3.1.3 DL-address-mapping [ISO/IEC 7498-1]

3.1.4 called-DL-address [ISO/IEC 7498-3]

3.1.5 calling-DL-address [ISO/IEC 7498-3]

3.1.6 DL-connection [ISO/IEC 7498-1]

3.1.7 DL-connection-end-point [ISO/IEC 7498-1]

3.1.8 DL-connection-end-point-identifier [ISO/IEC 7498-1]

3.1.9 DL-connection-mode transmission [ISO/IEC 7498-1]

3.1.10 DL-connectionless-mode transmission [ISO/IEC 7498-1]

3.1.11 decentralized multi-end-point-connection [ISO/IEC 7498-1]

3.1.12 DL-duplex-transmission [ISO/IEC 7498-1]

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

3.1.14 flow control [ISO/IEC 7498-1]

3.1.15 (N)-layer [ISO/IEC 7498-1]
DL-layer (N=2)
Ph-layer (N=1)

3.1.16 layer-management [ISO/IEC 7498-1]

3.1.17 DL-local-view [ISO/IEC 7498-3]

3.1.18 multi-endpoint-connection [ISO/IEC 7498-1]

3.1.19 DL-name [ISO/IEC 7498-3]

3.1.20 naming-(addressing)-domain [ISO/IEC 7498-3]

3.1.21 peer-entities [ISO/IEC 7498-1]

3.1.22 primitive name [ISO/IEC 7498-3]

3.1.23 DL-protocol [ISO/IEC 7498-1]

3.1.24 DL-protocol-connection-identifier [ISO/IEC 7498-1]

3.1.25 DL-protocol-control information [ISO/IEC 7498-1]

3.1.26 DL-protocol-data-unit [ISO/IEC 7498-1]

3.1.27 DL-protocol-version-identifier [ISO/IEC 7498-1]

3.1.28 DL-relay [ISO/IEC 7498-1]

3.1.29 reassembling [ISO/IEC 7498-1]

3.1.30 reset [ISO/IEC 7498-1]

3.1.31 responding-DL-address [ISO/IEC 7498-3]

3.1.32 routing [ISO/IEC 7498-1]

3.1.33 segmenting [ISO/IEC 7498-1]

3.1.34 sequencing [ISO/IEC 7498-1]

3.1.35 (N)-service [ISO/IEC 7498-1]
DL-service (N=2)
Ph-service (N=1)

3.1.36 (N)-service-access-point [ISO/IEC 7498-1]
DL-service-access-point (N=2)
Ph-service-access-point (N=1)

3.1.37 DL-service-access-point-address [ISO/IEC 7498-3]

3.1.38 DL-service-connection-identifier [ISO/IEC 7498-1]

3.1.39 DL-service-data-unit [ISO/IEC 7498-1]

3.1.40 DL-simplex-transmission [ISO/IEC 7498-1]

3.1.41 DL-subsystem [ISO/IEC 7498-1]

3.1.42 systems-management [ISO/IEC 7498-1]

3.1.43 DL-user-data [ISO/IEC 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 DL-user-optional-facility

3.2.16 indication (primitive); acceptor.deliver (primitive)

3.2.17 multi-peer

3.2.18 request (primitive); requestor.submit (primitive)

3.2.19 requestor

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

3.2.21 submit (primitive)

3.2.22 symmetrical service

3.3 Common terms and definitions

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

NOTE Many definitions are common to more than one protocol Type; they are not necessarily used by all protocol Types.

3.3.1
DL-segment
single DL-subnetwork in which any of the connected DLEs may communicate directly, without any intervening DL-relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the period(s) of attempted communication

3.3.2
extended link
DL-subnetwork, consisting of the maximal set of links interconnected by DL-relays, sharing a single DL-name (DL-address) space, in which any of the connected DL-entities may communicate, one with another, either directly or with the assistance of one or more of those intervening DL-relay entities

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

3.3.3
frame
denigrated synonym for DLPDU

3.3.4
receiving DLS-user
DL-service user that acts as a recipient of DL-user-data

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

3.3.5
sending DLS-user
DL-service user that acts as a source of DL-user-data

3.4 Additional Type 22 definitions

3.4.1
acyclic data
data which is transferred from time to time for dedicated purposes

3.4.2
bit
unit of information consisting of a 1 or a 0

Note 1 to entry: This is the smallest data unit that can be transmitted.

3.4.3
cell
synonym for a single DL-segment which uses RTFL communication model

3.4.4
communication cycle
fixed time period between which the root device issues empty frames for cyclic communication initiation in which data is transmitted utilizing CDC and MSC

3.4.5
cycle time
duration of a communication cycle

3.4.6
cyclic
events which repeat in a regular and repetitive manner

3.4.7
cyclic communication
periodic exchange of frames

3.4.8
cyclic data
data which is transferred in a regular and repetitive manner for dedicated purposes

3.4.9
cyclic data channel
CDC
part of one or more frames, which is reserved for cyclic data

3.4.10
data
generic term used to refer to any information carried over a fieldbus

3.4.11
device
physical entity connected to the fieldbus

3.4.12
error
discrepancy between a computed, observed or measured value or condition and the specified or theoretically correct value or condition

3.4.13
gateway
device acting as a linking element between different protocols

3.4.14
inter-cell communication
communication between a RTFL device and a RTFN device or communication between a RTFL device and another RTFL device in different cells linked by RTFN

3.4.15
interface
shared boundary between two functional units, defined by functional characteristics, signal characteristic, or other characteristics as appropriate

3.4.16
intra-cell communication
communication between a RTFL device and another RTFL device in the same cell

3.4.17
link
synonym for DL-segment

3.4.18
logical double line
sequence of root device and all ordinary devices processing the communication frame in forward and backward direction

3.4.19
master clock
global time base for the PCS mechanism

3.4.20
message
ordered sequence of octets intended to convey data

3.4.21
message channel
MSC
part of one or more frames, which is reserved for acyclic data

3.4.22
network
set of devices connected by some type of communication medium, including any intervening repeaters, bridges, routers and lower-layer gateways

3.4.23
open network
any ISO/IEC 8802-3 -based network with no further restrictions

3.4.24
ordinary device
OD
slave in the communication system, which utilizes RTFL for cyclic and acyclic data interchange with other ODs in the same logical double line

3.4.25
precise clock synchronization
PCS
mechanism to synchronize clocks of RTFL devices and maintain a global time base

3.4.26
process data
data designated to be transferred cyclically or acyclically for the purpose of processing

3.4.27
process data object
dedicated data object(s) designated to be transferred cyclically or acyclically for the purpose of processing

3.4.28
protocol
convention about the data formats, time sequences, and error correction in the data exchange of communication systems

3.4.29
root device
RD
master in the communication system, which organises, initiates and controls the RTFL cyclic and acyclic data interchange for one logical double line

3.4.30
real time frame line
RTFL
communication model communicating in a logical double line

3.4.31
real time frame network
RTFN
communication model communicating in a switched network

3.4.32
switch
MAC bridge as defined in IEEE 802.1D

3.4.33
round trip time
transmission time needed by a DLPDU from the RD to the last OD in forward and backward direction

3.4.34
timing signal
time-based indication of the occurrence of an event, commonly as an interrupt signal, used for DL-user synchronization

3.4.35
topology
physical network architecture with respect to the connection between the stations of the communication system

3.5 Common symbols and abbreviations

NOTE Many symbols and abbreviations are common to more than one protocol Type; they are not necessarily used by all protocol Types.

CIDR	Classless Inter-Domain Routing
DHCP	Dynamic Host Configuration Protocol
DL-	Data-link layer (as a prefix)
DLC	DL-connection
DLCEP	DL-connection-end-point
DLE	DL-entity
DLL	DL-layer
DLPCI	DL-protocol-control-information
DLPDU	DL-protocol-data-unit
DLM	DL-management
DLME	DL-management entity
DLMS	DL-management service
DLPDU	DL-protocol-data-unit
DLS	DL-service
DLSAP	DL-service-access-point
DLSDU	DL-service-data-unit
DNS	Domain name server
FCS	Frame check sequence
FIFO	First-in first-out
IANA	Internet Assigned Numbers Authority

IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
OSI	Open systems interconnection
Ph-	Physical layer (as a prefix)
PhE	Ph-entity
PhL	Ph-layer
QoS	Quality of service
RFC	Request for comments
UTF	Unicode transformation format

3.6 Additional Type 22 symbols and abbreviations

ACK	Acknowledgement
ADL	ACK data length
CDC	Cyclic data channel
CDCL	CDC line
CDCLPM	CDCL protocol machine
CDCN	CDC network
CDCNPM	CDCN protocol machine
CDCS	CDC send
CL	Communication layer
CMD	Command
DA	Device address or destination address
DMR	Delay measurement read
DMS	Delay measurement send
FHPM	Frame handling protocol machine
ID	Identification
IP	Internet protocol
IPv4	IP version 4

IPv6	IP version 6
IRQ	Interrupt request
MAC	Medium access control
MC	Master clock
MSC-MTP	Message channel message transfer protocol
MSC	Message channel
MSCL	MSC line
MSCLPM	MSCL protocol machine
MSCN	MSC network
MSCNPM	MSCN protocol machine
MSCR	MSC read
MSCS	MSC send
MSS	Maximum segment size
NMPM	Net management protocol machine
NV	RTFL network verification
OD	Ordinary device
PD	Previous device
PID	Packet ID
PCS	Precise clock synchronization
PCSC	PCS configuration
PM	Protocol machine
RD	Root device
RTF	Real time frame
RTFL	Real time frame line
RTFLCFG	RTFL configuration
RTFLCTL	RTFL control

RTFN	Real time frame network
RTFNCS	RTFN connection setup
RTFNCR	RTFN connection release
RTFNSNR	RTFN Scan network read
RX	Receive direction
SA	Source address
SYNC	Synchronization
SYNC_START	SYNC start
SYNC_STOP	SYNC stop
TCP	Transmission control protocol
TSU	Time stamping unit
TX	Transmit direction
UDP	User datagram protocol

3.7 Conventions

3.7.1 Abstract syntax conventions

The DL syntax elements related to DLPDU structure are described as shown in Table 1.

- Frame part denotes the element that will be replaced by this reproduction.
- Data field is the name of the elements.
- Data Type denotes the type of the terminal symbol.
- Value/Description contains the constant value or the meaning of the parameter.

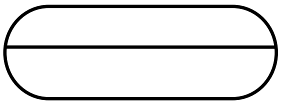
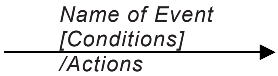
Table 1 – DLPDU element definition

Frame part	Data field	Data type	Value/description

3.7.2 Protocol machine description conventions

The protocol sequences are described by means of protocol machines. For the specification of protocol machines within this part of this standard, the following graphical description language is used. Table 2 specifies the graphical elements of this description language and their meanings.

Table 2 – Conventions for protocol machine description

Graphical element	Description
	Each state of a protocol machine is uniquely identified using a descriptive name An action, if required, is performed by the protocol machine in this particular state
	A transition between different states of a protocol machine is caused by an event or a particular condition Conditions describing the state of a part of or of the whole system can be stated which have to be fulfilled to perform a certain transition Additionally actions which are performed when performing a certain transition can be stated
	The initial state of a protocol machine is labeled using this symbol

4 Overview of the DL-protocol

4.1 Operating principle

Type 22 of this series of international standards describes a real-time communication technology based on ISO/IEC 8802-3 for the requirements of automation technology. For the purpose of fast intra-machine communication Type 22 describes a communication model and protocol (RTFL) for fast real-time communication. Furthermore, networking of several parts of an automation system into an overall system is supported by the specification of a second communication model and protocol (RTFN). Type 22 is designed as a multi-master bus system.

Type 22 networks utilize ISO/IEC 8802-3 communication DLPDUs for both communication models.

4.2 Communication model

4.2.1 Overview

Type 22 technology essentially specifies two communication models with corresponding protocols. RTFL communication is intended for fast machine communication while RTFN provides for the networking of individual machines or cells. The corresponding protocols aim to offer an equal set of services for cyclic process data exchange as well as for acyclic message data communication.

For RTFL communication model, communication follows a line topology. RTFL communication is based on cyclic data transfer in an ISO/IEC 8802-3 DLPDU. This basic cyclic data transfer is provided by a special device, the root device (RD). Root devices act as communication master to cyclically initiate communication. The DLPDUs originated by the root device are passed to the Type 22 ordinary devices (OD). Each ordinary device receives the DLPDU, writes its data and passes the DLPDU on. A RTFL network requires exactly one root device. The last ordinary device of a RTFL network sends the processed DLPDU back. The DLPDU is transferred back along exactly the same way to the root device so that it is returned by the first ordinary device to the root device as response DLPDU. In backward direction, the ordinary devices read their relevant data from the DLPDU.

For RTFN communication model, communication is based on point to point connections between participating devices.

Networking of different RTFL parts or cells of an automation system into an overall automation system is supported by the usage of RTFN communication and corresponding gateways.

4.2.2 RTFL device reference model

Type 22 services are described using the principles, methodology and model of ISO/IEC 7498-1 (OSI). The OSI model provides a layered approach to communications standards, whereby the layers can be developed and modified independently. The Type 22 specification defines functionality from top to bottom of a full OSI model. Functions of the intermediate OSI layers, layers 3 to 6, are consolidated into either the Type 22 data-link layer or the DL-user. The device reference model for a Type 22 RTFL device is shown in IEC 61158-3-22, Figure 1.

4.2.3 RTFN device reference model

Type 22 services are described using the principles, methodology and model of ISO/IEC 7498-1 (OSI). The OSI model provides a layered approach to communications standards, whereby the layers can be developed and modified independently. The Type 22 specification defines functionality from top to bottom of a full OSI model. Functions of the intermediate OSI layers, layers 3 to 6, are consolidated into either the Type 22 data-link layer or the DL-user. The device reference model for a Type 22 RTFN device is shown in IEC 61158-3-22, Figure 2.

4.3 Topology

4.3.1 RTFL topology

A Type 22 network utilizing the RTFL communication model shall support all commonly used topologies like tree, star and line.

The ordinary devices for the RTFL communication model should provide two physical communication interfaces as described in ISO/IEC 8802-3 to allow the set-up of a line structure without additional infrastructure components. For performance reasons this is the preferred RTFL topology.

4.3.2 RTFN topology

A Type 22 network utilizing the RTFN communication model shall support all commonly used topologies like tree, star and line.

4.4 DLPDU processing

4.4.1 Communication model RTFL

4.4.1.1 DLPDU generation

For a Type 22 network utilizing the RTFL communication model the frame generation concept is specified. This concept shall be applied by the root device within a RTFL network to cyclically initiate communication. DLPDU generation depicts the generation of an RTFL DLPDU into the RTFL network to be processed by all participating ordinary devices for communication purposes.

If the ordinary devices are arranged in a physical line DLPDUs should be directly forwarded from one interface to the next interface and processed on-the-fly (cut-through).

4.4.1.2 Error detection

For the purpose of error detection, each RTFL device shall verify the FCS (Frame Check Sequence) on receipt of the DLPDU. On forwarding the DLPDU to the next participant, the

FCS is recalculated and re-written. In the case of a detected FCS failure, a device shall indicate this failure using a dedicated error bit within a Type 22 frame and writes the revised FCS. Other ODs can determine by this error bit the validity of the DLPDU content.

A root device can detect the presence of errors within a communication cycle by the usage of the following three options.

- Verification of the Frame Check Sequence (FCS) to detect failures between RD and the first OD.
- Verification of the error bit to detect the presence of a failure between two ODs.
- Verification of the round trip time for each DLPDU to detect the loss of DLPDUs.

4.4.2 Communication model RTFN

This communication model does not apply any particular DLPDU processing procedures. DLPDUs are directly sent between communicating entities.

4.5 General communication mechanisms

4.5.1 Cyclic data channel (CDC)

The cyclic data channel (CDC) is intended for cyclic process data transfer.

For RTFL devices, the cyclic data channel (CDCL) is a DLPDU section reserved within one or more DLPDUs for cyclic data. The devices write data in packets in the CDC and extract relevant data packets. Packets are identified by unique IDs (packet ID, PID). Each OD copies the packets in forward direction to the DLPDU to make data available. All other ODs in the double line can read those packets on the return direction of the DLPDU.

The uniqueness of a packet has to be assured by configuration for the whole communication environment of the packet. Packets used for inter-cell communication between different RTFL networks are labeled by a PID which is unique within all involved DL-segments, while packets within different communication environments (for example different DL-segments) can be labeled with the same PID unique only within their communication environment.

For RTFN devices, the cyclic data channel (CDCN) is based on cyclic point-to-point communication between two devices. Several unidirectional communication links are set up between devices. Each link may be configured with a different cycle time. This communication does not use acknowledgements. Large data volume is handled similar to the RTFL DLPDU sequences. Communication can be based either at MAC or UDP level. A base RTFN cycle time has to be specified for RTFN devices. This time specifies a limit on how often CDCN messages are sent by the RTFN devices.

4.5.2 Message channel (MSC)

The message channel is intended for acyclic communication. Data is transferred in messages. The devices write data in addressed packets to the message channel, while the message channel can contain several messages. The individual message length is variable. A specific protocol, the message channel transfer protocol (MSC-MTP) is used to serve this channel.

For RTFL devices, the message channel consists of one DLPDU (MSCL-frame) per communication cycle for acyclic data and inter-cell communication. There are three different priorities for messages which are used to reserve bandwidth according to the importance of the message. The priority is derived out of the service type of the message content. The size of MSCL-frames is configurable. If the MSC cannot hold all messages in a cycle, an OD can assign transfer space in one of the next cycles (assigning). Reservation includes prioritization depending on the service.

For RTFN devices, the message channel (MSCN) utilizes UDP/IP and the MSC message transfer protocol. There is no prioritization necessary.

4.6 Gateway

The gateway acts as linking element between RTFL and RTFN. In addition, it is a gateway between Type 22 networks and the open network. A device incorporating gateway functionality can be an OD or a RD. The Gateway contains the following functionalities:

- MSC Gateway
- CDC Gateway

Gateway functionality is necessary to enable inter-cell communication. Inter-cell acyclic communication is communication between a RTFL device and a RTFN device or communication between a RTFL device and another RTFL device in a different logical double line (also called cell) interconnected via RTFN using a gateway. Messages must be transported over RTFL MSC (MSCL) as well as over RTFN MSC (MSCN) in order to reach their destination. The different addressing schemas in MSCL and MSCN require a translation as a gateway function. The MSC extended addressing mode facilitates inter-cell acyclic communication.

Inter-cell cyclic communication is the exchange of process data across the RTFN and RTFL network boundaries. The communication parameters for the process data packets contain packet identifiers. The packets are routed across the RTFN/RTFL boundary and the gateway takes care of the packet id resolution.

4.7 Interaction models

4.7.1 Overview

Depending on the specified communication models RTFL and RTFN Type 22 networks utilize different interaction models for cyclic data exchange.

4.7.2 Producer-consumer

Communication model RTFL uses the producer-consumer interaction model. It involves a single producer and a group of zero or more consumer(s). The model is characterized by an unconfirmed service requested by the producer to distribute its cyclic data and a correlated service indication in all available consumers.

4.7.3 Publisher-subscriber

Communication model RTFN utilizes the publisher-subscriber push interaction model for cyclic data exchange. Publisher-subscriber interactions involve a single publisher and a group of one or more subscribers. Two services are used, one confirmed and one unconfirmed. The confirmed service is used by the subscriber to request to join the publishing. The response to this request is returned to the subscriber. The unconfirmed service is used by the publisher to distribute its cyclic data to subscribers.

5 DLPDU structure

5.1 Overview

Networks of this protocol type use standard ISO/IEC 8802-3 DLPDUs for transporting Type 22 DLPDUs.

5.2 Data types and encoding rules

5.2.1 Overview

To be able to exchange meaningful data across a Type 22 network, the format of this data and its meaning have to be known by communicating entities. This specification models this by the concept of data types.

The encoding rules define the representation of values of data types and the transfer syntax for the representation. Values are represented as bit sequences. Bit sequences are transferred in sequences of octets. For numerical data types the encoding is big endian style.

The data types and encoding rules shall be valid for the DLL services and protocols. The encoding rules for the DLPDU are specified in ISO/IEC 8802-3. The DLSDU of an ISO/IEC 8802-3 DLPDU is an octet string. The transmission order within octets depends upon MAC and PhL encoding rules.

5.2.2 Transfer syntax for bit sequences

For transmission across Type 22 DLL a bit sequence is reordered into a sequence of octets. Let b = b_{n-1} to b_0 be a bit sequence. Denote k a non-negative integer such that:

$$8(k - 1) < n < 8k$$

Then b is transferred in k octets assembled as shown in Table 3. The bits b_i, i > n of the lowest numbered octet are do not care bits.

Octet 1 is transmitted first and octet k is transmitted last. Hence the bit sequence is transferred as follows across the network:

..., b15, ..., b8, b7, b6, ..., b0

Table 3 – Transfer syntax for bit sequences

Octet number	1.	(k-1).	k.
—	$b_{8k-1} – b_{8k-8}$	$b_{15} – b_8$	$b_7 – b_0$

5.2.3 Unsigned Integer

Data of basic data type Unsignedn has values in the non-negative integers. The value range is 0 to 2^n-1. The data is represented as bit sequences of length n. The bit sequence

$$b = b_{n-1} \ldots b_0$$

is assigned the value

$$\text{Unsignedn}(b) = b_{n-1}\times 2^{n-1} + \ldots + b_1\times 2^1 + b_0\times 2^0$$

EXAMPLE The value 276 = 0x0114 with data type Unsigned16 is transferred in two octets, first 0x01 and then 0x14.

The Unsignedn data types are transferred as specified in Table 4. Unsigned data types as Unsigned1 to Unsigned7 and Unsigned9 to Unsigned15 will be used too. In this case the next element will start at the first free bit position. The grouping of such data types shall end without resulting gaps.

Table 4 – Transfer syntax for data type Unsignedn

Octet number	1.	2.	3.	4.	5.	6.	7.	8.
Unsigned8	$b_7 – b_0$	—	—	—	—	—	—	—
Unsigned16	$b_{15} – b_8$	$b_7 – b_0$	—	—	—	—	—	—
Unsigned24	$b_{23} – b_{16}$	$b_{15} – b_8$	$b_7 – b_0$	—	—	—	—	—
Unsigned32	$b_{31} – b_{24}$	$b_{23} – b_{16}$	$b_{15} – b_8$	$b_7 – b_0$	—	—	—	—
Unsigned64	$b_{63} – b_{56}$	$b_{55} – b_{48}$	$b_{47} – b_{40}$	$b_{39} – b_{32}$	$b_{31} – b_{24}$	$b_{23} – b_{16}$	$b_{15} – b_8$	$b_7 – b_0$

5.2.4 Signed Integer

Data of basic data type Integern has values in the integers. The value range is from -2^{n-1} to $2^{n-1}-1$. The data is represented as bit sequences of length n. The bit sequence

$$b = b_{n-1} \ldots b_0$$

is assigned the value

$$\text{Signedn}(b) = b_{n-2}\times 2^{n-2} + \ldots + b_1\times 2^1 + b_0\times 2^0 \text{ if } b_{n-1} = 0$$

and, performing two's complement arithmetic,

$$\text{Signedn}(b) = - \text{Integern}(\hat{}b) - 1 \text{ if } b_{n-1} = 1$$

EXAMPLE The value –276 = 0xFEEC with data type Signed16 is transferred in two octets, first 0xFE and then 0xEC.

The Signedn data types are transferred as specified in Table 5. Integer data types as Signed1 to Signed7 and Signed9 to Signed15 will be used too. In this case the next element will start at the first free bit position. The grouping of such data types shall end without resulting gaps.

Table 5 – Transfer syntax for data type Signedn

Octet number	1.	2.	3.	4.
Signed8	$b_7 – b_0$	—	—	—
Signed16	$b_{15} – b_8$	$b_7 – b_0$	—	—
Signed32	$b_{31} – b_{24}$	$B_{23} – b_{16}$	$b_{15} – b_8$	$b_7 – b_0$

5.2.5 Octet Array

The data type OctetArray[*length]* is defined below; *length* is the length of the octet array.

ARRAY [length] OF Unsigned8 OctetArray[*length*]

5.3 DLPDU identification

Type 22 DLPDUs inside an ISO/IEC 8802-3 DLPDU shall be identified using the EtherType DLPDU field. The Type field shall contain the value 0x9C40, which is the unique Type field number that has been allocated by the IEEE EtherType Field Registration Authority for Type 22 telegrams.

NOTE This field number refers to Type 22 communication.

UDP packets are delivered depending on the destination port. For Type 22 DLPDUs inside an UDP DLPDU, the port shall be 0x9C40, which is the unique port number assigned by the Internet Assigned Numbers Authority (IANA) for Type 22.

5.4 General DLPDU structure

5.4.1 Type 22 DLPDU inside an ISO/IEC 8802-3 DLPDU

The DLPDU structure for a Type 22 DLPDU inside an ISO/IEC 8802-3 DLPDU consists of the data entries as specified in Table 6.

Table 6 – Type 22 DLPDU inside an ISO/IEC 8802-3

Frame part	Data field	Data type	Value/description
ISO/IEC 8802-3	Destination Address	Unsigned8[6]	Destination address as specified in ISO/IEC 8802-3
	Source Address	Unsigned8[6]	Source address as specified in ISO/IEC 8802-3
	Length/Type	Unsigned8[2]	0x9C40 (Type 22)
	Type 22 DLPDU	—	As specified in 5.4.4
	PAD	Unsigned8[n]	Shall be inserted if DLPDU is shorter than 64 octets as specified in ISO/IEC 8802-3
ISO/IEC 8802-3 FCS	FCS	Unsigned32	Frame Check Sequence coding as specified in ISO/IEC 8802-3

5.4.2 Type 22 DLPDU inside a VLAN tagged ISO/IEC 8802-3 DLPDU

The DLPDU structure for a Type 22 DLPDU inside a VLAN tagged ISO/IEC 8802-3 DLPDU consists of the data entries as specified in Table 7.

Table 7 – Type 22 DLPDU inside a VLAN tagged ISO/IEC 8802-3 DLPDU

Frame part	Data field	Data type	Value/description
ISO/IEC 8802-3	Destination Address	Unsigned8[6]	Destination address as specified in ISO/IEC 8802-3
	Source Address	Unsigned8[6]	Source address as specified in ISO/IEC 8802-3
	VLAN Tag	Unsigned8[4]	0x8100 (tag protocol identifier) 0xC000 (two Unsigned8s tag control information as specified in IEEE 802.1Q)
	Length/Type	Unsigned8[2]	0x9C40 (Type 22)
	Type 22 DLPDU	—	As specified in 5.4.4
	PAD	Unsigned8[n]	Shall be inserted if DLPDU is shorter than 64 octets as specified in ISO/IEC 8802-3
ISO/IEC 8802-3 FCS	FCS	Unsigned32	Frame Check Sequence as specified in ISO/IEC 8802-3

5.4.3 Type 22 DLPDU inside an UDP DLPDU

The DLPDU structure for a Type 22 DLPDU inside an ISO/IEC 8802-3 DLPDU consists of the data entries as specified in Table 8.

Table 8 – Type 22 DLPDU inside an UDP DLPDU

Frame part	Data field	Data type	Value/description
ISO/IEC 8802-3	Destination address	Unsigned8[6]	Destination address as specified in ISO/IEC 8802-3
	Source address	Unsigned8[6]	Source MAC address as specified in ISO/IEC 8802-3
	VLAN Tag (optional)	Unsigned8[4]	0x8100 (tag protocol identifier) 0xC000 (two Unsigned8s tag control information as specified in IEEE 802.1Q)
	Length/Type	Unsigned8[2]	0x0800 (IP)
IP as specified in RFC 791	Version header length	Unsigned8	0x45 (IP version(4) header length (5*4 octets))
	Service	Unsigned8	0x00 (IP type of service)
	Total length	Unsigned16	IP total length of service
	Identification	Unsigned16	IP identification packet for fragmented service
	Flags and fragments offset	Unsigned16	IP flags and IP fragment number
	Ttl	Unsigned8	Time to live
	Protocol	Unsigned8	0x11 (IP sub-protocol – this value is reserved for UDP)
	Header checksum	Unsigned16	IP header checksum
	Source IP address	Unsigned8[4]	IP source address of the originator
	Destination IP address	Unsigned8[4]	IP destination address of the recipient
UDP as specified in RFC 768	Src port	Unsigned16	UDP source port
	Dest port	Unsigned16	0x9C40 (UDP destination port)
	Length	Unsigned16	UDP length of DLPDU
	Checksum	Unsigned16	UDP checksum of DLPDU
	Type 22 DLPDU	—	As specified in 5.4.4
	Padding	Unsigned8[n]	Shall be inserted if DLPDU is shorter than 64 octets as specified in ISO/IEC 8802-3
FCS	FCS	Unsigned32	Frame Check Sequence as specified in ISO/IEC 8802-3

5.4.4 Type 22 DLPDU structure

5.4.4.1 Introduction

The data structure of a Type 22 DLPDU shall follow the general structure of a Type 22 DLPDU as specified in Table 9.

Table 9 – General structure of a Type 22 DLPDU

DLPDU part	Data field	Data type	Value/description
Type 22 DLPDU	Header	OCTET[1]	Defines the DLPDU type
	Payload	OCTET[0-1499]	The content of this entry depends on the header information

5.4.4.2 Header

The DLPDU header shall distinguish the various Type 22 DLPDUs. The DLPDU header structure is shown in Table 10.

Table 10 – DLPDU header structure

DLPDU part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	Identifies different DLPDU types

5.4.4.3 Payload

All transmitted data are permitted to have arbitrary bit sequences. The structure of data transmitted within payload field depends on the type of Type 22 DLPDUs.

5.5 Communication management DLPDUs

5.5.1 RTFL network verification DLPDUs

The RTFL network verification (NV) DLPDUs are Type 22 DLPDUs and shall follow the structure specified in Table 11, Table 12, Table 13 and Table 14.

Table 11 – Network verification prepare DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x10: NV prepare message
NV header	Sequence number	Unsigned16	Continuous sequence number
	Version	Unsigned8	RTFL network verification version
NV data	MAC RD	Unsigned8[6]	MAC address of RD

Table 12 – Network verification environment DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x11: NV environment message
NV header	Sequence number	Unsigned16	Continuous sequence number
	Version	Unsigned8	RTFL network verification version
NV data	MAC RD	Unsigned8[6]	MAC address of the root device
	MAC PD	Unsigned8[6]	MAC address of the predecessor

Table 13 – Network verification information DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x12: NV information message
NV header	Sequence number	Unsigned16	Continuous sequence number
	Version	Unsigned8	RTFL network verification version
NV data	Identification data	—	Contains identification data of a device as specified in 5.5.3

Table 14 – Network verification acknowledgement DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x13: NV acknowledgement message
NV header	Sequence number	Unsigned16	Sequence number of acknowledged DLPDU
	Version	Unsigned8	RTFL network verification version
NV data	ACK type	Unsigned8	Indicates the type of the acknowledged DLPDU

5.5.2 RTFN scan network DLPDUs

The RTFN scan network (RTFNSNR) DLPDUs are Type 22 DLPDUs and shall follow the structure specified in Table 15 and Table 16.

Table 15 – RTFN scan network request DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x80: RTFN scan network request

Table 16 – RTFN scan network response DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x81: RTFN scan network response
RTFNSNR data	Identification data	—	Contains identification data of a device as specified in 5.5.3

5.5.3 Identification data

5.5.3.1 Identification data specification

The identification data field is part of NV DLPDUs as specified in 5.5.1 and RTFNSNR DLPUs as specified in 5.5.2. Identification data shall follow the structure specified in Table 17 or Table 18.

Table 17 – Identification data

Frame part	Data field	Data type	Value/description
Identification data	Version	Unsigned16	Version of the Type 22 protocol implementation Static: 0x0001
	SerialNumber	Unsigned32	Serial number of the device
	Vendor ID	Unsigned32	Identifies the vendor
	ProductNumber	Unsigned32	Product number of device
	RevisionNumber	Unsigned32	Revision number of device
	SymbolicDeviceNameSize	Unsigned16	Length of the symbolic device name string in octets
	SymbolicDeviceName	Unsigned16[64]	Symbolic device name
	DeviceType	Unsigned32	0x00: unknown type
	PhyLinkPort1	Unsigned8	Link state of port 1
	PhyLinkPort2	Unsigned8	Link state of port 2
	RTF support	Unsigned8	0x00: no support

Frame part	Data field	Data type	Value/description
			0x01: RTFL supported 0x10: RTFN supported 0x11: RTFL and RTFN supported
	IPv4 address	Unsigned8[4]	IPv4 address of the device
	IPv4 subnet mask	Unsigned8[4]	IPv4 subnet mask
	IPv4 gateway	Unsigned8[4]	IPv4 address of default gateway
	IPv4 1. DNS server	Unsigned8[4]	IPv4 address of 1. DNS server
	IPv4 2. DNS server	Unsigned8[4]	IPv4 address of 2. DNS server
	IPv6 address	Unsigned8[16]	IPv6 address of the device
	IPv6 CIDR	Unsigned8	IPv6 category address
	IPv6 1. DNS server	Unsigned8[16]	IPv6 address of 1. DNS server
	IPv6 2. DNS server	Unsigned8[16]	IPv6 address of 2. DNS server
	UseDHCP server	Unsigned8	Indicates the usage of a DHCP server
	MAC PD	Unsigned8[6]	MAC address of the predecessor
	Device MAC	Unsigned8[6]	MAC address of this device
	DeviceRole	Unsigned8	Indicates the role of this device within the network

Table 18 – Identification data v2

Frame part	Data field	Data type	Value/description
Identification data	Version	Unsigned16	Version of the Type 22 protocol implementation Static: 0x0002
	SerialNumber	Unsigned32	Serial number of the device
	Vendor ID	Unsigned32	Identifies the vendor
	ProductNumber	Unsigned32	Product number of device
	RevisionNumber	Unsigned32	Revision number of device
	SymbolicDeviceNameSize	Unsigned16	Length of the symbolic device name string in octets
	SymbolicDeviceName	Unsigned16[64]	Symbolic device name
	DeviceType	Unsigned32	0x00: unknown type
	RTFN support	Unsigned8	RTFN support per RTF2 table
	RTFL support	Unsigned8	RTFL support per RTF2 table
	PhyLinkPort1	Unsigned8	Link state of port 1 per PhyLinkPortX table
	PhyLinkPort2	Unsigned8	Link state of port 2 per PhyLinkPortX table
	IP network scanner	Unsigned32	IP of network scanner
	MACAddress	Unsigned8[6]	MAC address of the device
	MACAddress of scan relayed device	Unsigned8[6]	MAC address of the scan relayed device
	IPv4 address	Unsigned8[4]	IPv4 address of the device
	IPv4 subnet mask	Unsigned8[4]	IPv4 subnet mask
	IPv4 gateway	Unsigned8[4]	IPv4 address of default gateway
	IPv4 1. DNS server	Unsigned8[4]	IPv4 address of 1. DNS server
	IPv4 2. DNS server	Unsigned8[4]	IPv4 address of 2. DNS server
	IPv6 address	Unsigned8[16]	IPv6 address of the device
	IPv6 CIDR	Unsigned8	IPv6 category address

Frame part	Data field	Data type	Value/description
	IPv6 1. DNS server	Unsigned8[16]	IPv6 address of 1. DNS server
	IPv6 2. DNS server	Unsigned8[16]	IPv6 address of 2. DNS server
	UseDHCP server	Unsigned8	Indicates the usage of a DHCP server
	MAC PD	Unsigned8[6]	MAC address of the predecessor
	MAC S	Unsigned8[6]	MAC address of the successor
	Device address	Unsigned16	Address of the device
	Device line position	Unsigned8	Position in the double line
	RTFL cycle start time	Unsigned8[8]	Start time for the RTFL cycle
	RTFL cycle time	Unsigned32	RTFL cycle time
	Watchdog trigger	Unsigned32	Interval for the watchdog
	CDC frames	Unsigned8	Number of CDC frames
	CDC frame size	Unsigned16	Data size of CDC frame
	MSC size	Unsigned16	Data size of MSC frame
	MSC max. message size	Unsigned16	Max. message size for MSC
	Interrupt 1 start time	Unsigned8[8]	Start time for interrupt 1
	Interrupt 1 cycle time	Unsigned32	Cycle time for interrupt 1
	Interrupt 2 start time	Unsigned8[8]	Start time for interrupt 2
	Interrupt 2 cycle time	Unsigned32	Cycle time for interrupt 2
	PAA	Unsigned16	Estimated RTFL PAA

5.5.3.2 PhyLinkPortX

The PhyLinkPortX field is part of the identification data and its coding is depicted in Table 19.

Table 19 – PhyLinkPortX

Bit	Value	Description
0 to 1	00	10 MBit/s data transfer rate
	01	100 MBit/s data transfer rate
	10	1 GBit/s data transfer rate
	11	10 GBit/s data transfer rate
2 to 3	00	Reserved
4	0	Half duplex
	1	Full duplex
5	0	Auto negotiation off
	1	Auto negotiation on
6	0	No link
	1	Link
7	0	Port not present
	1	Port present

5.5.3.3 RTF support

The RTF support field is part of the identification data and its coding is depicted in Table 20.

Table 20 – RTF support

Bit	Value	Description
0 to 3	0000	RTFL not supported
	0001	RTFL supported
4 to 7	0000	RTFN not supported
	0001	RTFN supported

5.5.3.4 RTF2 support

The RTF2 support field is part of the identification data and its coding is depicted in Table 21.

Table 21 – RTF2 support

Bit	Value	Description
0	0	Not supported
	1	Supported
1	0	Not switched
	1	Switched
2	0	RTFL Chip not present
	1	RTFL Chip present
3	0	No scan received
	1	Scan received
4	0	PHY1 not supported
	1	PHY1 supported
5	0	PHY1 not active
	1	PHY1 active
6	0	PHY2 not supported
	1	PHY2 supported
7	0	PHY2 not active
	1	PHY2 active

5.5.3.5 UseDHCP

The UseDHCP field is part of the identification data and its coding is depicted in Table 22.

Table 22 – UseDHCP

Bit	Value	Description
0	0	IPv4 static IP not used
	1	IPv4 static IP used
1	0	IPv4 DHCP not used
	1	IPv4 DHCP used
2	0	IPv4 automatic IP not used
	1	IPv4 automatic IP used
3	x	Reserved
4	0	IPv6 static IP not used
	1	IPv6 static IP used
5	0	IPv6 DHCP not used
	1	IPv6 DHCP used
6	0	IPv6 automatic IP not used
	1	IPv6 automatic IP used
7	x	Reserved

5.5.3.6 DeviceRole

The DeviceRole field is part of the identification data and its coding is depicted in Table 23.

Table 23 – DeviceRole

Bit	Value	Description
0	0	RD not supported
	1	RD supported
1	0	Gateway not supported
	1	Gateway supported
2	0	OD not supported
	1	OD supported
3	0	Switch not supported
	1	Switch supported
4	0	PCS not supported
	1	PCS supported
5 to 7	000	Reserved

5.5.4 RTFN connection management DLPDU

The RTFN connection management (RTFNCM) DLPDU is a Type 22 DLPDU and shall follow the structure specified in Table 24.

Table 24 – RTFN connection management DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x40: CDCN subscribe request 0x41: CDCN subscribe acknowledge 0x42: CDCN unsubscribe 0x44: CDCN unpublished
RTFNCM Header	Version	Unsigned8	CDCN protocol version
	ID data count	Unsigned16	Indicates the number of ID data packets listed within ID data field
RTFNCM data	ID data 1	—	Indicates the 1st process data object of the connection which hast to be established as specified in 5.5.5
	…	—	—
	ID data N	—	Indicates the Nth process data object of the connection which hast to be established as specified in 5.5.5

The CDCN connection still alive DLPDU is a Type 22 DLPDU and shall follow the structure specified in Table 25.

Table 25 – CDCN connection still alive DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x43: CDCN still alive

5.5.5 ID data

The ID data field is part of the RTFN connection management DLPDU. Its structure is specified in Table 26.

Table 26 – ID data

Frame part	Data field	Data type	Value/description
ID data	Packet ID	Unsigned24	Unique identifier for a process data object
	UseUDP	Unsigned8	Indicates the usage of pure ISO/IEC 8802-3 DLPDUs or UDP protocol
	IP address	Unsigned8[4]	IP address of the subscriber

5.5.6 RTFL control DLPDU

The RTFL control (RTFLCTL) DLPDU is a Type 22 DLPDU and shall follow the structure specified in Table 27.

Table 27 – RTFL control DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x30: RTFL control (CL reset)

5.5.7 RTFL configuration DLPDUs

The RTFL configuration (RTFLCFG) DLPDUs are Type 22 DLPDUs and shall follow the structure specified in Table 28 and Table 29.

Table 28 – RTFL configuration DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x20: RTFLCFG frame
RTFLCFG header	Sequence number	Unsigned16	Continuous sequence number
	Version	Unsigned8	RTFL config version Static: 0x01
RTFLCFG data	Previous MAC address	Unsigned8[6]	MAC address of the predecessor device
	Next MAC address	Unsigned8[6]	MAC address of the successor device
	Next MAC alternative	Unsigned8[6]	MAC address of an alternative successor
	Device address	Unsigned16	Device address of the device
	MSCShortMsgSize	Unsigned16	Indicates maximal message size for un-segmented transfer
	Number of frames	Unsigned8	Indicates the number of frames for CDC and MSC communication channel
	Cycle time	Unsigned32	Indicate the cycle time of the communication cycle
	RTF timeout	Unsigned32	Timeout monitoring
	Master clock DA	Unsigned16	Indicates the device address of the device which integrates the master clock
	IPv4 address	Unsigned8[4]	IPv4 address of the device
	IPv4 subnet mask	Unsigned8[4]	IPv4 subnet mask
	IPv4 gateway	Unsigned8[4]	IPv4 address of default gateway
	IPv4 1. DNS server	Unsigned8[4]	IPv4 address of 1. DNS server
	IPv4 2. DNS server	Unsigned8[4]	IPv4 address of 2. DNS server
	IPv6 address	Unsigned8[16]	IPv6 address of the device
	IPv6 CIDR	Unsigned8	IPv6 category address
	IPv6 1. DNS server	Unsigned8[16]	IPv6 address of 1. DNS server
	IPv6 2. DNS server	Unsigned8[16]	IPv6 address of 2. DNS server
	UseDHCP server	Unsigned8	Indicates the usage of a DHCP server

Table 29 – RTFL configuration acknowledgement DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x21: RTFLCFG acknowledgement frame
RTFLCFG header	Sequence number	Unsigned16	Continuous sequence number
	Version	Unsigned8	RTFL config version Static: 0x01

5.5.8 RTFL configuration 2 DLPDUs

The RTFL configuration 2 (RTFLCFG2) DLPDUs are Type 22 DLPDUs and shall follow the structure specified in Table 30 and Table 31.

Table 30 – RTFL configuration 2 DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x20: RTFLCFG frame
RTFLCFG header	Sequence number	Unsigned16	Continuous sequence number
	Version	Unsigned8	RTFL config version Static: 0x02
RTFLCFG data	Previous MAC address	Unsigned8[6]	MAC address of the predecessor device
	Next MAC address	Unsigned8[6]	MAC address of the successor device
	Device address	Unsigned16	Device address of the device
	Device line position	Unsigned8	Position in the double line
	RTFL cycle start time	Unsigned8[8]	Start time for the RTFL cycle
	RTFL cycle time	Unsigned32	RTFL cycle time
	Watchdog trigger	Unsigned32	Interval for the watchdog
	CDC frames	Unsigned8	Number of CDC frames
	CDC frame size	Unsigned16	Data size of CDC frame
	MSC size	Unsigned16	Data size of MSC frame
	MSC max. message size	Unsigned16	Max. message size for MSC

Table 31 – RTFL configuration acknowledgement 2 DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x21: RTFLCFG acknowledgement frame
RTFLCFG2 header	Sequence number	Unsigned16	Continuous sequence number
	Version	Unsigned8	RTFL config version Static: 0x02

5.6 Cyclic data channel (CDC) DLPDUs

5.6.1 Cyclic data channel line (CDCL) DLPDU

The CDCL DLPDU is a Type 22 frame and shall follow the structure specified in Table 32.

Table 32 – CDCL DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x02: RTFL CDC write frame 0x03: RTFL CDC read frame
CDCL header	Cycle counter	Unsigned16	Indicates the number of the actual cycle
	Frame counter	Unsigned8	Indicates the number of a frame within a cycle
	Length	Unsigned16	Length in octets of CDC write pointer and cyclic data fields
	CDC write pointer	Unsigned16	Indicates the write section for cyclic communication
CDC payload	CDC data section	OctetArray[x]	Cyclic DLPDU data as specified in 5.7
CDCL status	Status	Unsigned8[1]	0x00: No failure 0x01: Check of FCS failed

5.6.2 Cyclic data channel network (CDCN) DLPDU

The CDCN DLPDU is a Type 22 frame and shall follow the structure specified in Table 33.

Table 33 – CDCN DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x60: RTFN CDC data frame
CDCN header	Version	Unsigned8	CDCN protocol version
	Size	Unsigned16	Indicates the size of cyclic data field
CDC payload	CDC data section	—	Cyclic DLPDU data as specified in 5.7

5.7 Cyclic data channel (CDC) DLPDU data

5.7.1 Cyclic data channel (CDC) DLPDU data arrangement

The arrangement of real-time data within the CDC data section shall follow the structure as specified in Table 34.

Table 34 – CDC DLPDU data arrangement

Frame part	Data field	Data type	Value/description
CDC data section	CDC packet 1	—	First configurable data object depicting in-/output data of participating devices
	…	—	—
	CDC packet N	—	Nth configurable data object depicting in-/output data of participating devices

5.7.2 Cyclic data channel (CDC) DLPDU data

The CDC DLPDU data is part of CDCL DLPDU as specified in 5.6.1 and CDCN DLPDU as specified in 5.6.2. The structure of CDCL DLPDU data shall be as specified in Table 35.

Table 35 – CDC DLPDU data

Frame part	Data field	Data type	Value/description
CDC packet	PID	Unsigned24	The packet ID uniquely identifies the process data object within a Type 22 network
	Len	Unsigned8	Length of the CDC DLPDU data packet including PID and Len field in octets
	Data	OctetArray [Len-4]	Process data

5.8 Message channel (MSC) DLPDUs

5.8.1 Message channel line (MSCL) DLPDU

5.8.1.1 Message channel line (MSCL) DLPDU specification

The MSCL DLPDU is a Type 22 frame and shall follow the structure specified in Table 36.

Table 36 – MSCL DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x00: MSC write frame 0x01: MSC read frame
MSCL Header	Cycle counter	Unsigned16	Indicates the number of the actual cycle
	MSCL control	Unsigned8	Contains control bits to set parameters for the communication
	System time	Unsigned64	Indicates the time at which the packet passed the master clock
	Reserved	Unsigned16	Reserved for further usage
	Length	Unsigned16	Length in octets of MSC write pointer and message data fields
	MSC write pointer	Unsigned16	Indicates the next write position in the message data section
	Assigned priority 1 count	Unsigned16	Indicates assigned priority 1 messages (highest priority)
	Assigned priority 2 count	Unsigned16	Indicates assigned priority 2 messages
	Assigned priority 3 count	Unsigned16	Indicates assigned priority 3 messages (lowest priority)
MSC data	MSC-MTP frame 1	—	Message data as specified in 5.9
	…	—	—
	MSC-MTP frame N	—	Message data as specified in 5.9
MSCL status	Status	Unsigned8	0x00: No failure 0x01: Check of FCS failed

5.8.1.2 MSCL control field

The MSCL control field is part of the MSCL DLPDU and its coding is depicted in Table 37.

Table 37 – MSCL control

Bit	Value	Description
0	1	Reset of assigned priority count fields, the previous applied priority reservations are invalid
1	1	Indicates that the line is running in diagnostic mode
2	1 0	Indicates that the PCS clocks are synchronized If a delay measurement is executed this bit is set to 0 until the delay measurement is finished
3	1	Timestamp is used for controlling local clock
4 to 7	0	Reserved for further usage

5.8.2 Message channel network (MSCN) DLPDU

The MSCN DLPDU is a Type 22 DLPDU and shall follow the structure specified in Table 38.

Table 38 – MSCN DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x70: MSCN message
MSC data	MSC-MTP frame	—	Message data as specified in 5.9

5.9 Message channel DLPDU data - MSC message transfer protocol (MSC-MTP)

5.9.1 Overview

Subclause 5.9 specifies the DLPDUs of the MSC message transfer protocol (MSC-MTP) which is used in MSC communication for both communication models RTFL and RTFN.

It provides a segmented and confirmed data transmission. If the data volume to be transferred is small enough, it is transferred using the MSC-MTP without segmentation. The maximum data volume which is transferred without segmentation is configuration dependent.

The MSC message transfer protocol shall be used for confirmed acyclic message exchange within MSCL DLPDUs as specified in 5.8.1 and MSCN DLPDUs as specified in 5.8.2.

5.9.2 MSC-MTP frame

5.9.2.1 MSC-MTP frame specification

The MSC-MTP frame is a Type 22 frame and shall follow the structure specified in Table 39.

Table 39 – MSC-MTP frame structure

Frame part	Data field	Data type	Value/description
MSC-MTP frame	Addr. type	Unsigned8	Indicates the addressing mode and the priority of the message
	Device DA	Unsigned16	Indicates the device address of the destination 0xFFFF: Broadcast address 0xFFFE: SEF multicast address
	Device SA	Unsigned16	Indicates the device address of the source
	Message length	Unsigned16	Indicates the total size of the MSC-MTP frame in octets
	IP address (optional)	Unsigned8[4] or Unsigned8[16]	Indicates the source or destination IP address in the case of extended addressing mode
	MSC-MTP frame data	—	As specified in 5.9.3

5.9.2.2 Address type

The MSC-MTP frame header shall distinguish between normal addressing mode and extended addressing mode. Extended addressing inserts an additional field (IP address) in the message header and facilitates inter-cell acyclic communication.

The address type field is part of the MSC-MTP frame and its coding is depicted in Table 40.

Table 40 – Address type

Bit	Value	Description
0 to 2	0000	Reserved
3 to 4	00	Priority 0 (not used)
	01	Priority 1
	10	Priority 2
	11	Priority 3
5	0	IP version 4
	1	IP version 6
6 to 7	00	Normal addressing mode
	01	Extended addressing mode, IP address is destination address
	10	Extended addressing mode, IP address is source address
	11	Reserved

5.9.3 MSC-MTP frame data

5.9.3.1 Init

The MSC-MTP Init is a Type 22 DLPDU and shall follow the structure specified in Table 41.

Table 41 – MSC-MTP Init structure

Frame part	Data field	Data type	Value/description
MSC-MTP frame data	CMD	Unsigned3	0x1: Init frame
	Handle	Unsigned5	Identifies the session
	Version	Unsigned8	Indicates the version of the message transfer protocol
	Reserved	Unsigned7	Reserved for upcoming control flags
	WithAck	Unsigned1	0x1: Confirmed communication expected 0x0: Unconfirmed communication expected (no Acknowledgment e.g. broadcast)
	Octet counter	Unsigned32	Indicates the message size

5.9.3.2 Init_Fast

The MSC-MTP Init_Fast is a Type 22 frame and shall follow the structure specified in Table 42.

Table 42 – MSC-MTP Init_Fast structure

Frame part	Data field	Data type	Value/description
MSC-MTP frame data	CMD	Unsigned3	0x2: Init_Fast frame
	Handle	Unsigned5	Identifies the session
	Version	Unsigned8	Indicates the version of the message transfer protocol
	Octet counter	Unsigned32	Indicates the number of transmitted data octets within this DLPDU
	Reserved	Unsigned7	Reserved for upcoming control flags
	WithAck	Unsigned1	0x1: Confirmed communication expected 0x0: Unconfirmed communication expected (no Acknowledgment e.g. broadcast)
	MSC-MTP message data		Data to be sent as specified in 5.9.4

5.9.3.3 Send

The MSC-MTP Send is a Type 22 DLPDU and shall follow the structure specified in Table 43.

Table 43 – MSC-MTP Send structure

Frame part	Data field	Data type	Value/description
MSC-MTP DLPDU data	CMD	Unsigned3	0x3: Send DLPDU 0x4: Send_Last DLPDU
	Handle	Unsigned5	Identifies the session
	Octet counter	Unsigned32	Indicates the number of transmitted data octets for this session including the content of this DLPDU
	MSC-MTP message data	—	Segment of data to be sent as specified in 5.9.4

5.9.3.4 Acknowledgement

The MSC-MTP Acknowledgement is a Type 22 DLPDU and shall follow the structure specified in Table 44.

Table 44 – MSC-MTP Acknowledgement structure

DLPDU part	Data field	Data type	Value/description
MSC-MTP DLPDU data	CMD	Unsigned3	0x5: Acknowledgement DLPDU
	Handle	Unsigned5	Identifies the session
	Version	Unsigned8	Indicates the version of the message transfer protocol
	Octet counter	Unsigned32	Confirmation of received octets
	MSS	Unsigned16	Maximum segment size

5.9.3.5 Abort

The MSC-MTP Abort is a Type 22 DLPDU and shall follow the structure specified in Table 45.

Table 45 – MSC-MTP Abort structure

DLPDU part	Data field	Data type	Value/description
MSC-MTP DLPDU data	CMD	Unsigned3	0x0: Abort DLPDU
	Handle	Unsigned5	Identifies the session to be aborted
	Reason	Unsigned32	0x1: General error 0x2: Timeout 0x3: Out of memory 0x7: Unexpected segment 0xC: Unknown Version
	CMD	Unsigned3	CMD of the last DLPDU the abort sender received
	Handle	Unsigned5	Identifies the session of the last DLPDU the abort sender received

5.9.4 MSC-MTP message data encoding

5.9.4.1 Overview

The MSC-MTP message data depicts the payload of the MSC-MTP protocol. The MSC service used by a DLS-user and different DL-services available for the usage by DL-users are based on it.

5.9.4.2 MSC-MTP message data specification

The general structure of message data shall follow the structure specified in Table 46.

Table 46 – Data structure of a message

DLPDU part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	Defines the type of service
	MSC service data	OctetArray[x]	Contains service data

5.10 Time synchronization

5.10.1 DelayMeasurement start

The DelayMeasurement start service shall be encoded as specified in Table 47.

Table 47 – DelayMeasurement start encoding

DLPDU part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	0xF0: Indicates RTFL communication layer service
MSC service data	CL CMD	Unsigned8	0x01: DelayMeasurement start
	CMD handle	Unsigned8	Session identification number
	Repeat count	Unsigned8	Indicates the number of communication cycles used for propagation delay measurement

5.10.2 DelayMeasurement read

The DelayMeasurement read service shall be encoded as specified in Table 48.

Table 48 – DelayMeasurement read encoding

DLPDU part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	0xF0: Indicates RTFL communication layer service
MSC service data	CL CMD	Unsigned8	0x02: DelayMeasurement read
	CMD handle	Unsigned8	Session identification number
	RTFL-delay	Unsigned32	Indicates the average delay between DLPDUs

5.10.3 PCS configuration

The PCS configuration service shall be encoded as specified in Table 49.

Table 49 – PCS configuration encoding

DLPDU part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	0xF0: Indicates RTFL communication layer service
MSC service data	CL CMD	Unsigned8	0x03: PCS configuration
	CMD handle	Unsigned8	Session identification number
	Clock configuration	Unsigned32	Contains the configuration data for clock adjustment

5.10.4 Time synchronization service

The time synchronization service shall be encoded as specified in Table 50 and Table 51.

Table 50 – Time synchronization service request

DLPDU part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	0xF4: Indicates common communication layer service
MSC service data	CL CMD	Unsigned8	0x12: Sync_Start request
	CMD handle	Unsigned8	Session identification number
	Sync ID	Unsigned16	Indicates the network wide unique ID for the requested sync interrupt

Table 51 – Time synchronization service response

DLPDU part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	0xF4: Indicates common communication layer service
MSC service data	CL CMD	Unsigned8	0x13: Sync_Start response
	CMD handle	Unsigned8	Session identification number
	Sync ID	Unsigned16	Indicates the network wide unique ID for the requested sync interrupt
	Start time	Unsigned64	Indicates the start time of the sync interrupt

6 Telegram timing and DLPDU handling

6.1 Communication mechanism

6.1.1 Communication model RTFL

6.1.1.1 Overview

The Type 22 RTFL DLL transfers data in a cyclic manner. Data transfer is handled by telegram transfer from one device to the next along a logical double line. The line corresponds to the logical addressed device sequence and not necessarily to the physical topology. Therefore it is called a logical double line.

Data transmission is initiated by the root device (RD) cyclically generating the RTF Ethernet DLPDUs and sending it to the first ordinary device (OD) in the logical double line. Each OD in the line receives these Ethernet DLPDUs from its predecessor, writes its data into the DLPDUs and sends them on to the next OD in the logical double line. Addressing and line setup is handled using MAC addresses. Each OD knows the MAC address of its logically next and previous device according to the configuration.

The last OD in the line writes its data to the DLPDU but also reads required data and returns the DLPDU to the logically previous OD. The RTFs are transferred along exactly the same way back to the RD and thus making a double line. In backward direction, the ODs read their relevant data from the RTF. This enables the exchange of data between ODs in one bus cycle.

The frame processing units enable concurrent on-the-fly (cut-through) processing of Type 22 DLPDUs in forward and backward direction. Data to be sent is written in forward direction while receive data is extracted in backward direction. Time stamping unit (TSU) is required to determine the exact point in time of the receipt of DLPDUs. It is used for PCS to enable the adjustment of the real-time clock.

6.1.1.2 DLPDU sequence

The sequence of transmitted Type 22 DLPDUs shall be repeated every communication cycle. The number and size of DLPDUs shall be dependent on the amount of process data and message data and is configuration dependent. Communication is always initiated by the root device.

The DLPDU length of the MSCL and CDCL DLPDUs shall remain constant and thus have the same length at each communication cycle. A communication cycle shall be characterized by the sequence of one MSCL DLPDU followed by at least one CDCL DLPDU. For the necessity of two or more CDCL DLPDUs, the DLPDUs shall be transmitted consecutive.

A communication cycle shall start with the MSCL DLPDU. A communication cycle shall be identified using the data field cycle counter as specified in 5.8.1 for MSCL and 5.6.1 for CDCL.

Figure 1 shows an arrangement of CDCL and MSCL DLPDUs. This figure shows an example of possible DLPDU arrangements and does not restrict other combinations which follow the specification stated above.

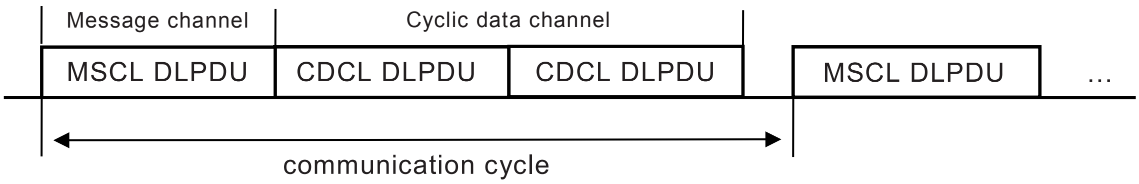


Figure 1 – DLPDU sequence

6.1.2 Communication model RTFN

The Type 22 RTFN DLL utilizes point-to-point connections. In order to set up a connection the communication participants use a protocol based on UDP as specified in IETF RFC 768. It is possible to set up several connections between communicating devices.

RTFN communication employs CDC and MSC mechanisms. Depending on the mechanism, communication utilizes either ISO/IEC 8802-3 DLPDUs or it is based on UDP protocol. The direct ISO/IEC 8802-3 DLPDU utilization reduces DLPDU processing delays and is suitable for sending process data. Alternatively, UDP is used for cyclic data with the advantage of routability. For MSC based message exchange, UDP and the MSC-MTP are used. Cyclic and acyclic communication is not based on a common communication cycle.

CDCN is based on cyclic sending of an individual or a sequence of Type 22 CDCN DLPDUs, depending on the process data volume. The destination device does not acknowledge the receipt of data; error handling in case of packet failure must be provided by the DL-user. A base RTFN cycle time shall be specified for RTFN devices during configuration. This time specifies a lower limit on how often CDCN messages are sent by the RTFN devices.

MSCN is based on acyclic sending of Type 22 MSCL DLPDUs. Utilizing the MSC-MTP the destination device acknowledges the receipt of data.

Figure 2 illustrates a possible communication relationship between two devices (Device 1 and Device 2). There is exactly one acyclic connection (MSCN) in each direction (connections B and C). Device 1 sends cyclic data using one connection to device 2 (connection A). Device 2 uses two connections to send cyclic data to Device 1. This is useful in the case of the necessity for different cycle times for connection D and E. This figure shows an example of possible communication relationships and does not restrict other combinations.

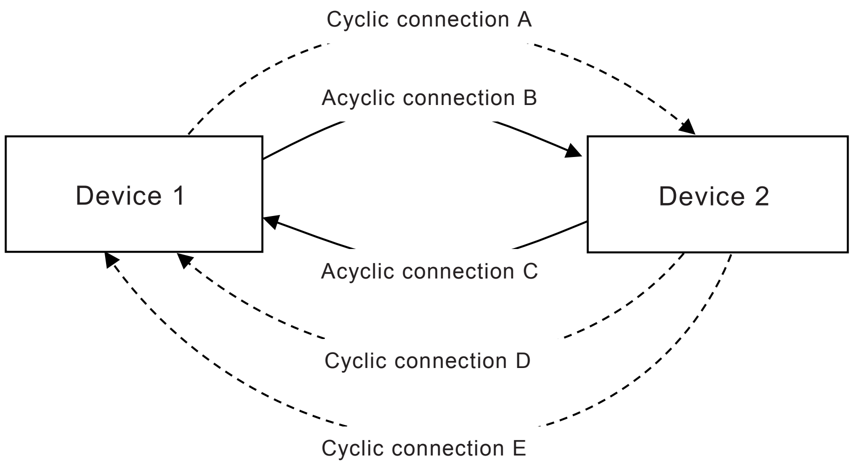


Figure 2 – Communication relationship RTFN device

6.2 Device synchronization

6.2.1 Communication model RTFL – precise clock synchronization

Precise clock synchronization (PCS) is used to synchronize devices. PCS describes a mechanism to maintain synchronized clocks within a Type 22 RTFL network. Since each device introduces a delay in the forward and backward direction (within the device and on the physical link), the propagation delay time between the global time base and the respective device clock shall be considered during the synchronization of the clocks.

The master clock (MC) within a Type 22 segment is the global time base. Its clock is used to synchronize the clocks of the other devices. The MC can be externally synchronized according to IEC 61588. It can be integrated into the root device, an ordinary device or incorporated as a stand-alone ordinary device. If the MC is a stand-alone device or an ordinary device, it shall be the first device after the root device.

The master clock shall transmit the system time in each MSCL DLPDU to all slaves. Each OD stores the time when each MSCL DLPDU passes the TSU in forward direction and in backward direction. The difference between these times can be requested by the RD. Furthermore each OD shall read the system time in forward direction out of the MSCL DLPDU.

The root device shall calculate the network delays during network initialization and operation and take these into account to configure the clock adjustment within ordinary devices. After completion of the delay measurement and the successful configuration of the clock adjustment each OD corrects its time based on the received system time. Furthermore, the RD configures an average time for each OD. If the current difference significantly differs from the average value during normal operation, the OD shall react in sending an error message or in ignoring the current value.

6.2.2 Communication model RTFN

For the necessity of device synchronization, synchronization services according to IEC 61588 shall be used to synchronize RTFN devices. In the case of the necessity for device synchronization, RTFN devices shall act as ordinary clock. It is recommended that in addition RTFN devices should act as boundary clocks.

Additionally, the management node PTP device type may be supported. It can be combined with any of the two PTP device types ordinary clock or boundary clock or it can be integrated within a non-synchronized RTFN device.

Each RTFN device shall at least support the IEC 61588 default PTP profile for use with the delay request-response mechanism with the PTP profile 00-1B-19-00-01-00 in version 1.0.

7 Type 22 protocol machines

7.1 RTFL device protocol machines

7.1.1 Overview

Figure 3 depicts the general protocol machine structure within a Type 22 RTFL device by showing its protocol machines and their interaction.

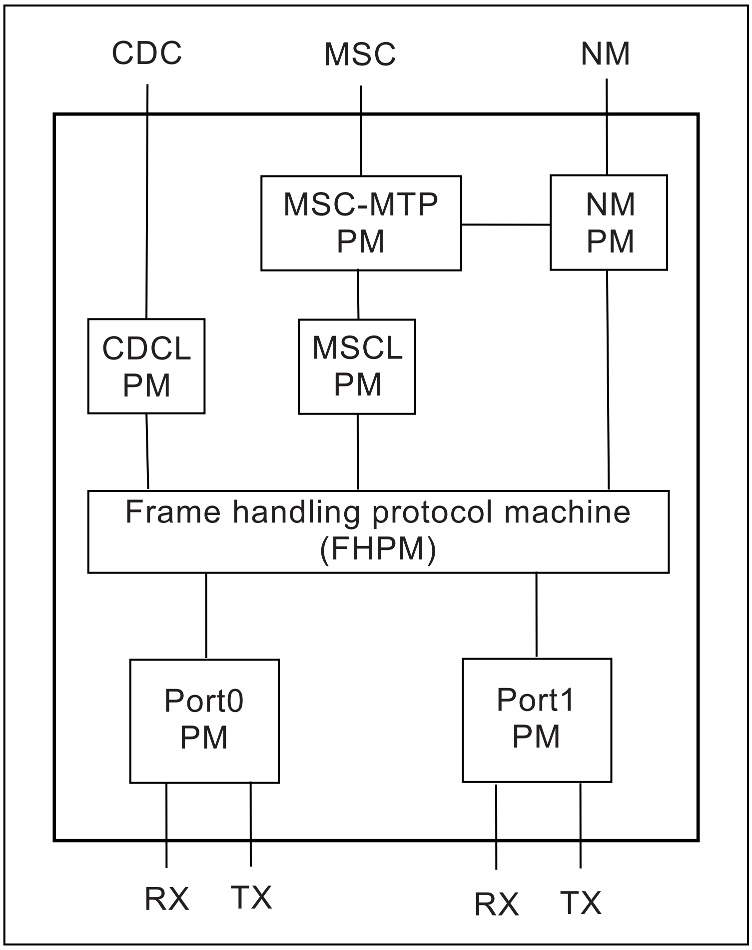


Figure 3 – Overview RTFL device protocol machines

7.1.2 PortX protocol machine (PortX PM)

The PortX PM provides the interconnection between frame handling protocol machine (FHPM) and the reconciliation sublayer and media independent interface of the physical layer according to ISO/IEC 8802-3 for one designated port of a RTFL device. There exists no explicit protocol machine for ports as it follows the rules defined for ports in ISO/IEC 8802-3.

7.1.3 Frame handling protocol machine (FHPM)

The frame handling protocol machine processes the ISO/IEC 8802-3 DLPDUs. FHPM splits incoming DLPDUs up and extracts all Type 22 DLPDUs. It maps the different incoming Type 22 DLPDUs to the different protocol machines CDCLPM, MSCLPM and NMPM. Furthermore, the arrangement of Type 22 DLPDUs within outgoing ISO/IEC 8802-3 DLPDUs issued by the protocol machines CDCLPM, MSCLPM, NMPM and PCSPM is handled.

FHPM consists of two independent sub-PMs, each responsible for the DLPDU processing for one logical processing direction (i.e. forward direction for data writing, backward direction for data extraction) and therefore interacting with its corresponding PortX PM. Figure 4 illustrates the protocol machine for sending of Type 22 DLPDUs.

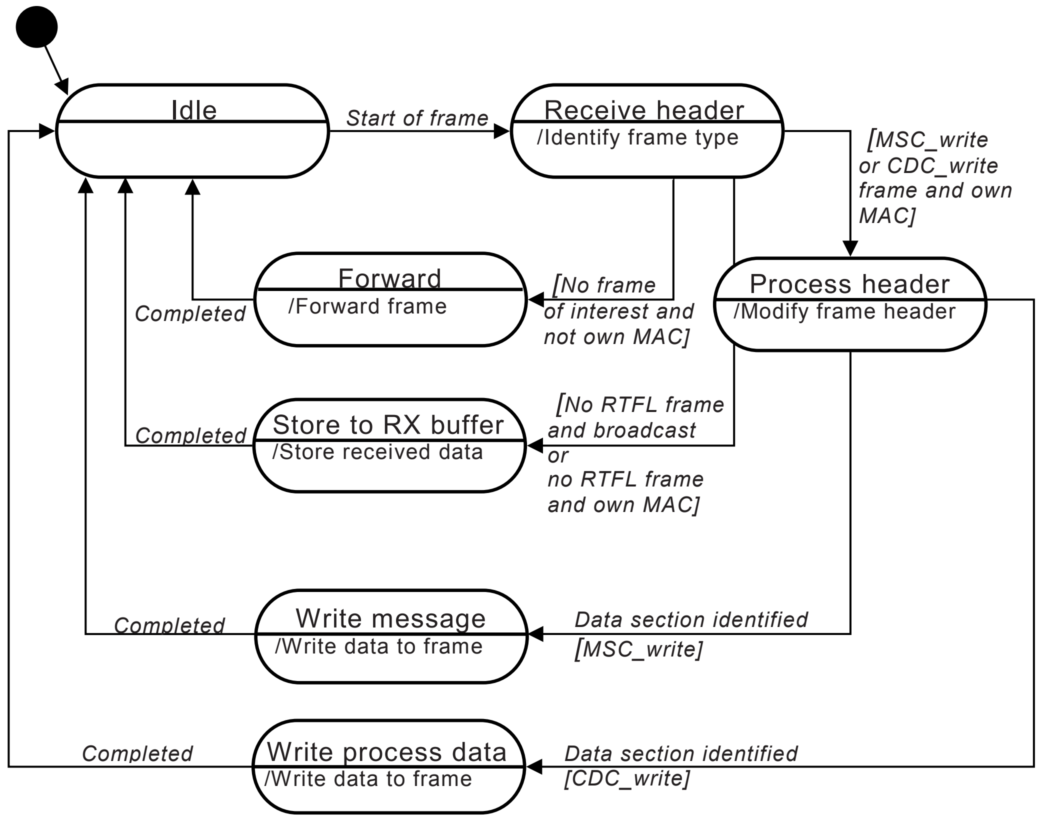


Figure 4 – Protocol machine send DLPDU procedure

Figure 5 illustrates the protocol machine for the receipt of Type 22 DLPDUs.

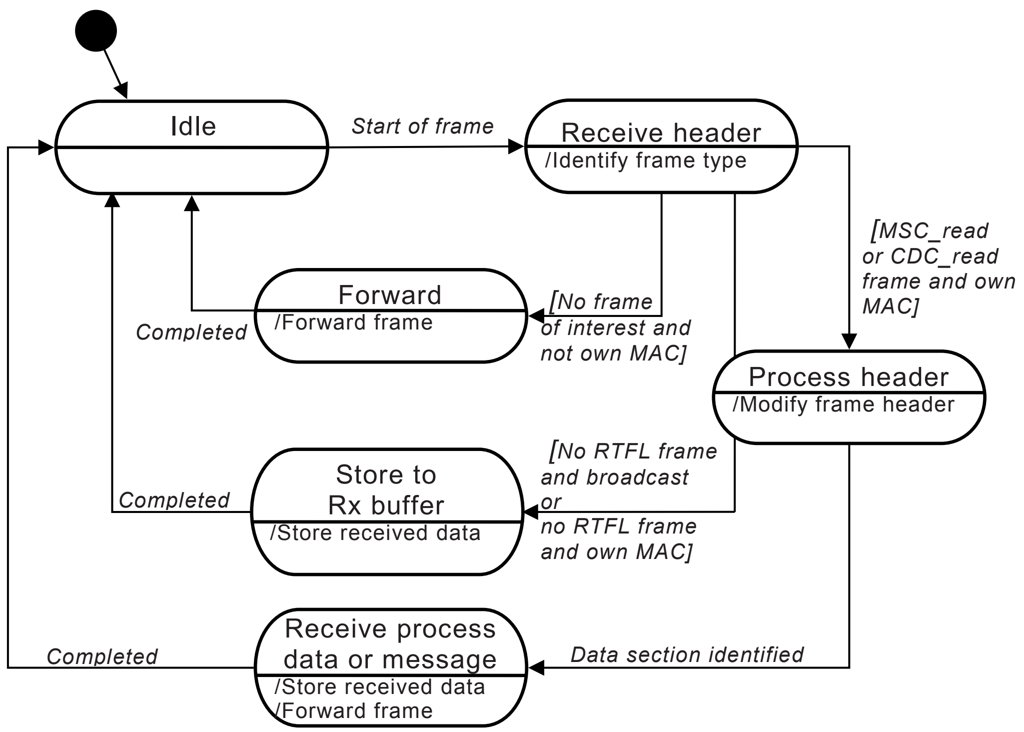


Figure 5 – Protocol machine receive DLPDU procedure

7.1.4 Cyclic data channel line protocol machine (CDCLPM)

7.1.4.1 Overview

CDCL protocol machine handles the exchange of process data objects between DLS-user and FHPM. The CDCLPM combines or extracts process data objects according to the CDCL protocol specified within this standard and forwards the service requests to the FHPM or to the DLS-user.

7.1.4.2 CDCL send sequence

Figure 6 depicts the sequence of necessary actions and operations to send Type 22 CDC DLPDUs.

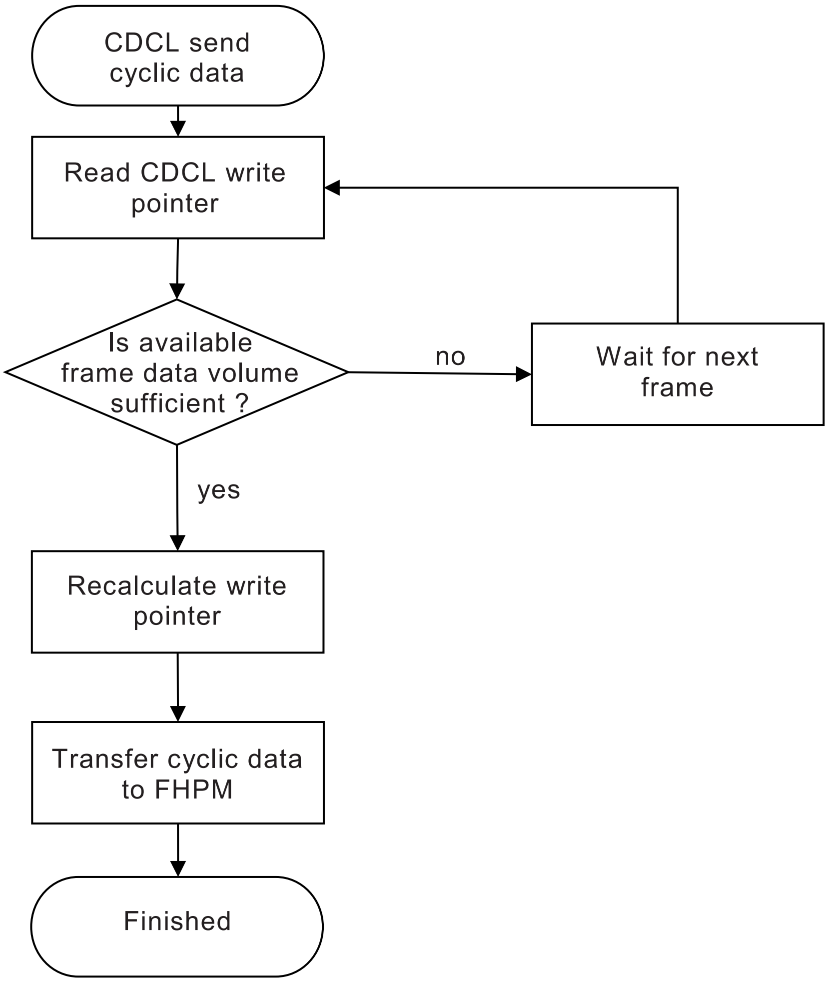
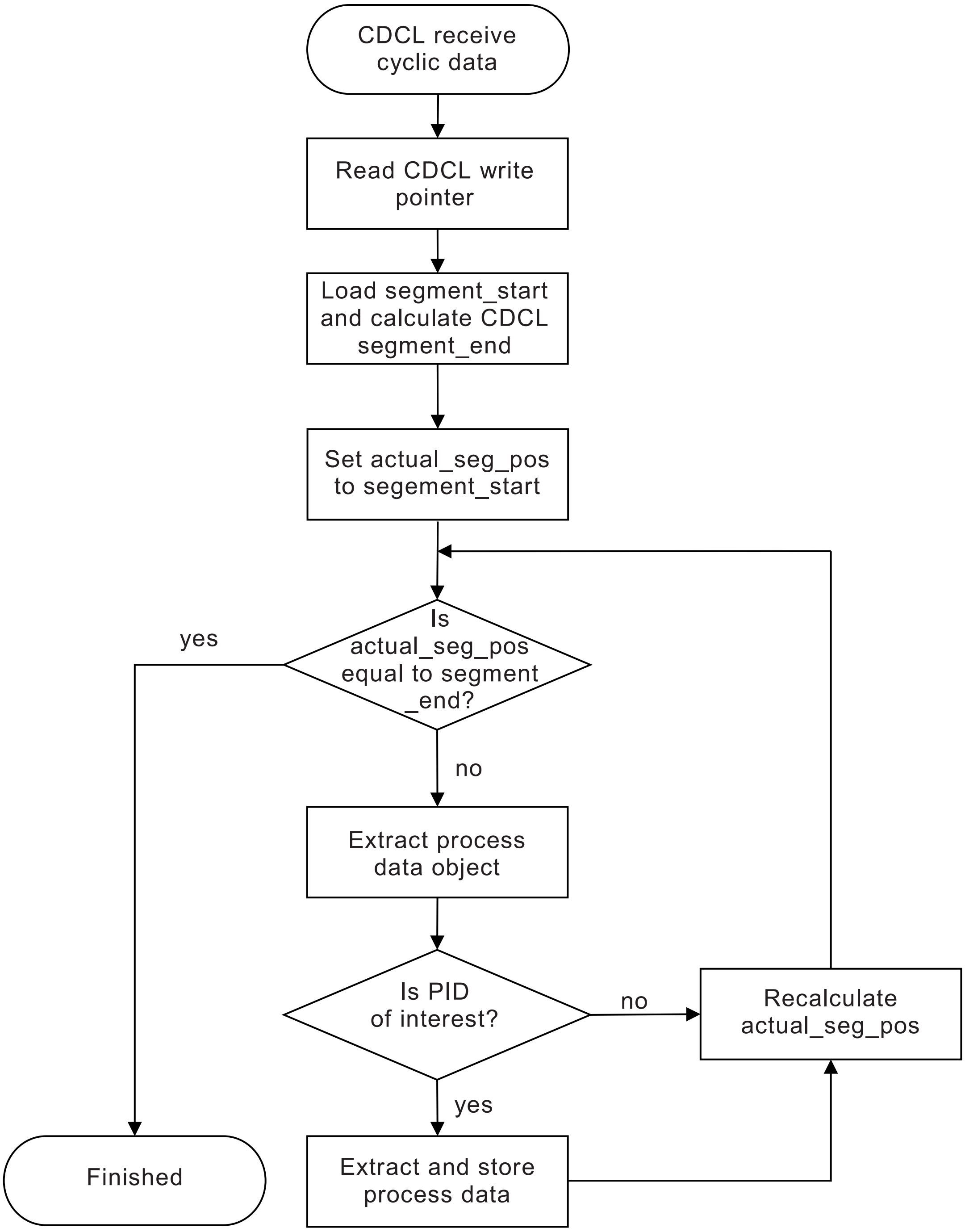


Figure 6 – CDCL send cyclic data sequence

7.1.4.3 CDCL receive sequence

Figure 7 depicts the sequence of necessary actions and operations to receive Type 22 CDC DLPDUs.



NOTE segment_end, segment_start and actual_seg_pos are symbolic expressions and are used to describe the CDC data section within a CDCL DLPDU as specified in 5.6.1 and the position within this data section.

Figure 7 – CDCL receive cyclic data sequence

7.1.5 Message channel line protocol machine (MSCLPM)

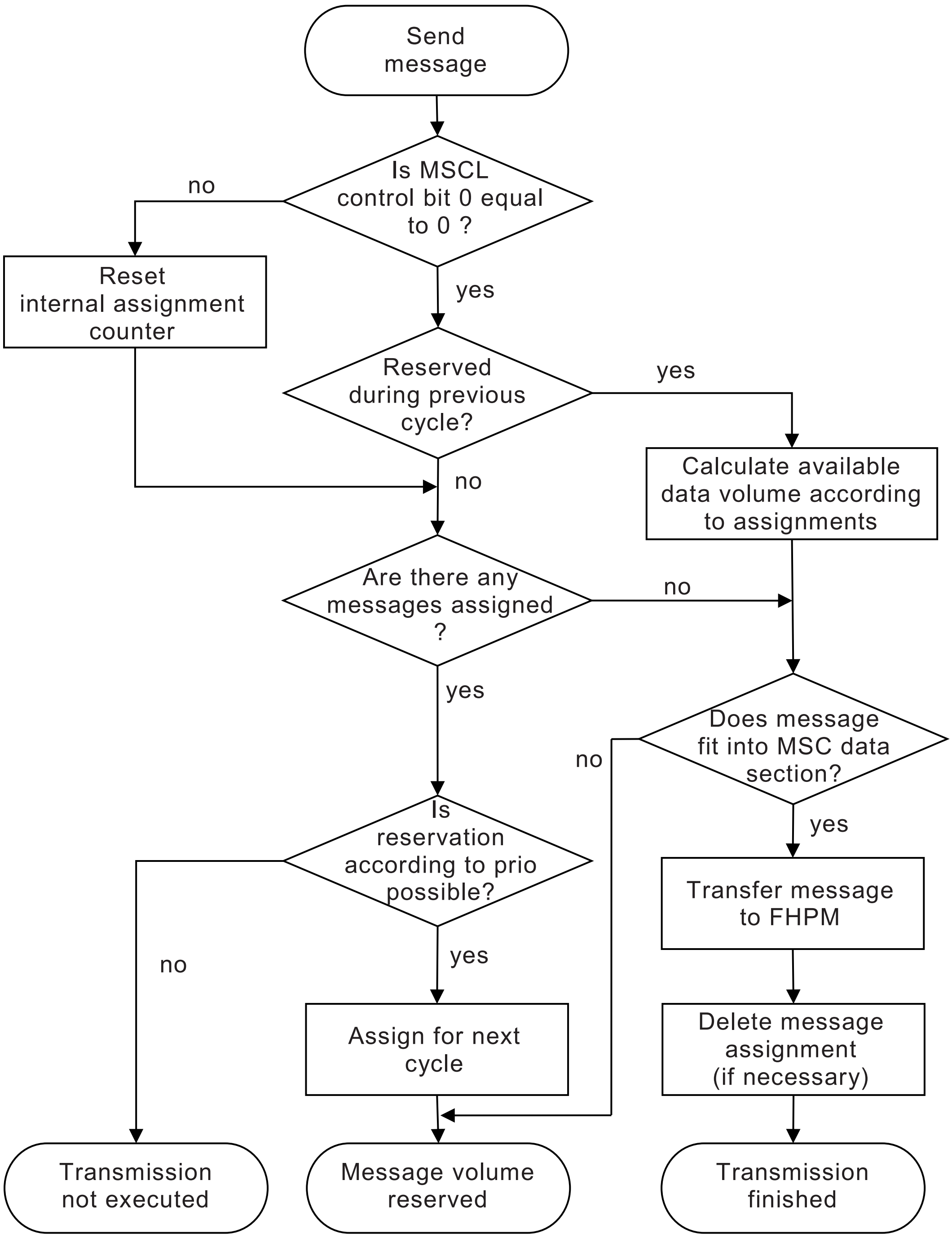
7.1.5.1 Overview

MSCL protocol machine handles the exchange of acyclic message data between MSC-MTP PM and FHPM. The MSCLPM combines or extracts MSC DLPDU data objects according to the MSCL protocol specified within this standard and forwards the service requests and responses to the MSC-MTP PM.

The sending and receiving of MSC DLPDU data objects follows the send and receive sequences depicted in 7.1.5.2 and 7.1.5.3.

7.1.5.2 MSCL send sequence

Figure 8 illustrates the MSCL send sequence used for the transmission of MSC DLPDU data objects within a Type 22 RTFL device.

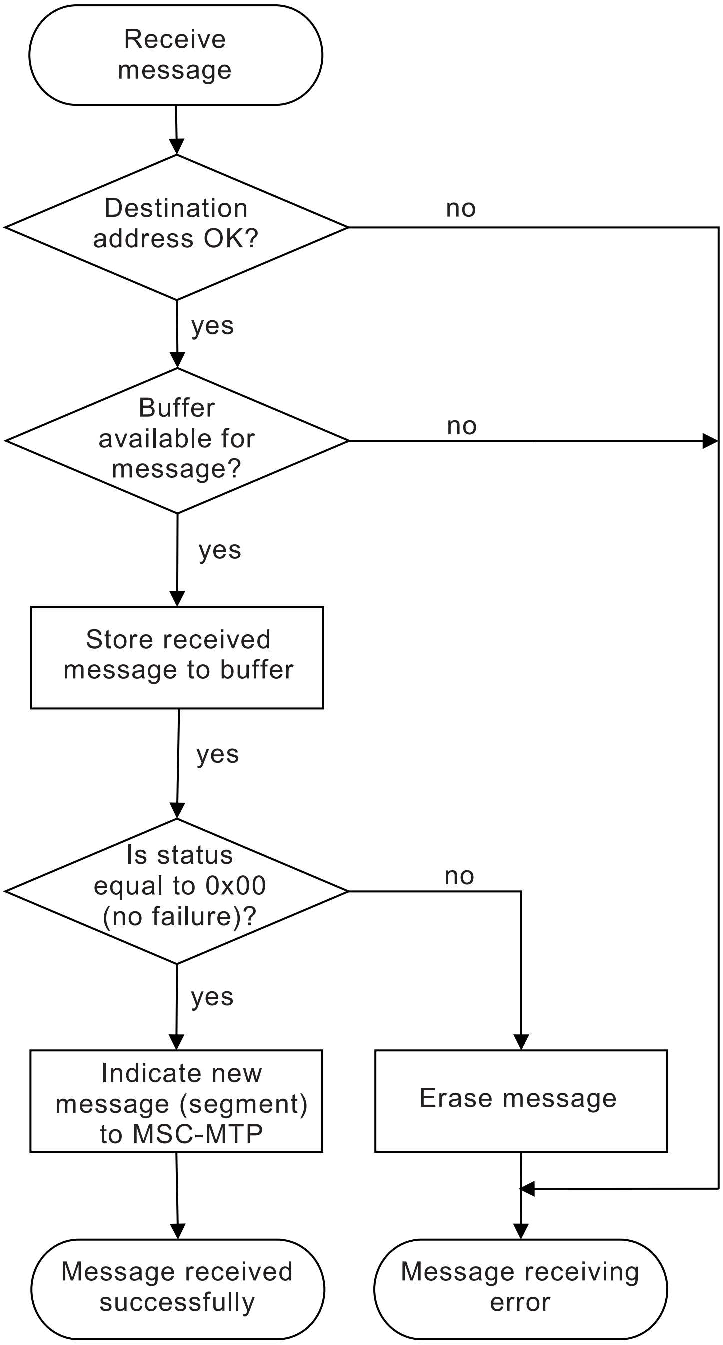


NOTE MSCL control is a particular field of the MSCL DLPDU.

Figure 8 – MSCL send sequence

7.1.5.3 MSCL receive sequence

Figure 9 illustrates the MSCL receive sequence used for the receipt of MSC DLPDU data objects within a Type 22 RTFL device.



NOTE Status is a particular field of the MSCL DLPDU.

Figure 9 – MSCL receive sequence

7.1.6 Message channel message transfer protocol protocol machine (MSC-MTP PM)

As specified in 7.3.

7.1.7 Net management protocol machine (NMPM)

7.1.7.1 Overview

Net management procedures are functionally processed in response to net management service requests submitted by the DLS-user and events caused by the network. Net management protocol machine handles the exchange of layer management data and commands between DLS-user, MSC-MTP PM and FHPM. The NMPM combines or extracts net management DLPDUs according to the protocol specified within this standard and forwards the service requests and responses to the DLS-user.

NMPM handles the protocol behavior for the initialization of a Type 22 network and implements the start-up behavior for root devices and ordinary devices. The procedural sequences to commence communication within the Type 22 RTFL communication system are specified in 7.1.7.2.

Additionally, the protocol behavior of the delay measurement service and PCS configuration service are handled by NMPM. These are specified in 7.1.8.

Figure 10 depicts the network management protocol machine.

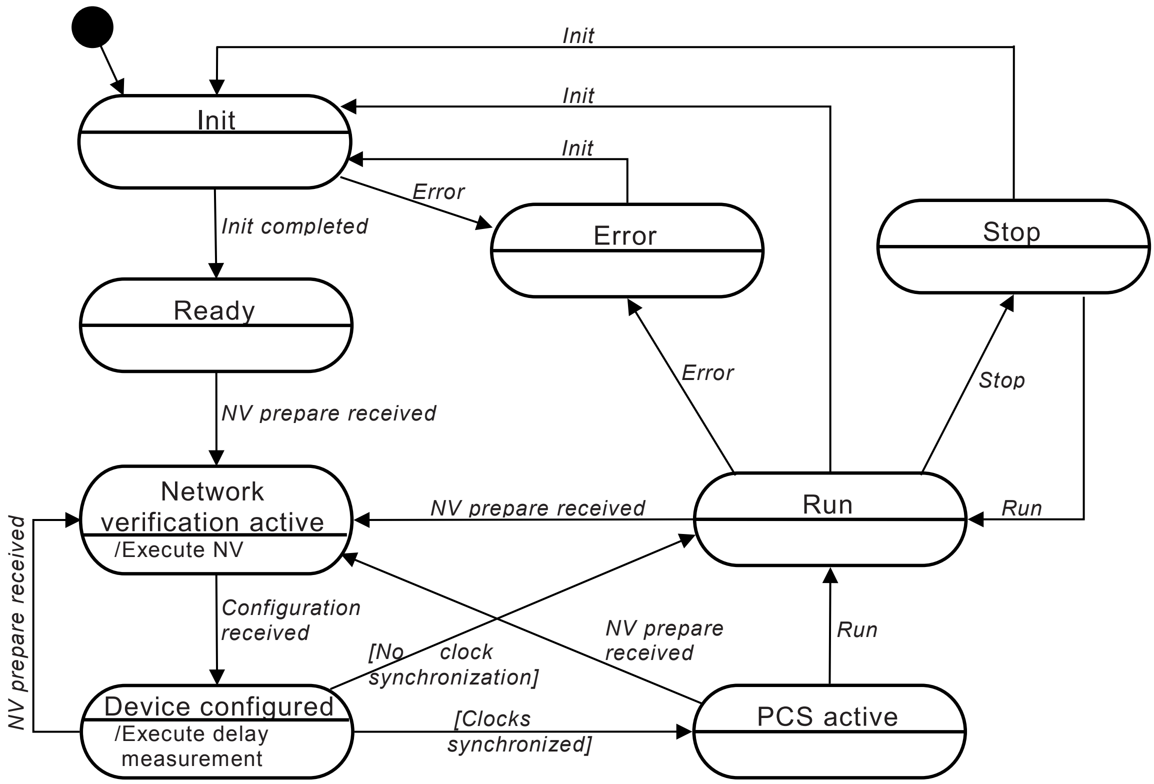


Figure 10 – Network management protocol machine

7.1.7.2 RTFL network verification

7.1.7.2.1 Overview

The RD is the device responsible for net management. It maintains the network configuration data for all ODs as configured and distributes the data to the ODs on RTFL initialization. It manages a list of all ODs participating in RTFL at runtime. This list includes for each OD its MAC address, device address and further information required for net management.

7.1.7.2.2 Initialization sequence root device

Figure 11 illustrates the individual configuration steps from the point of view of the RD.

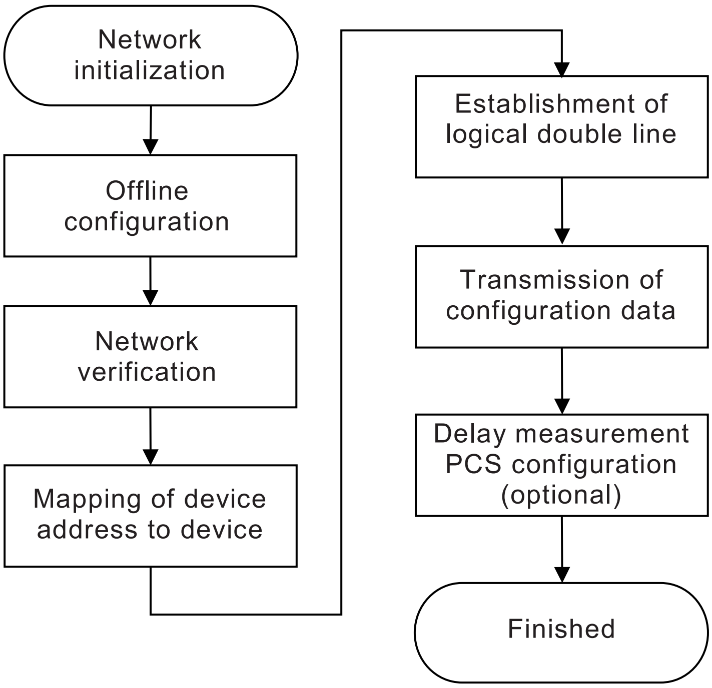


Figure 11 – Net management sequence at system boot up

7.1.7.2.3 Initialization sequence ordinary device

The initialization sequence is initiated by the RD. The ordinary devices are in power on state, i.e. all ODs indicate Ready in their network management protocol machines (see Figure 10). Initiated by the RD each OD processes the initialization sequence illustrated in Figure 12.

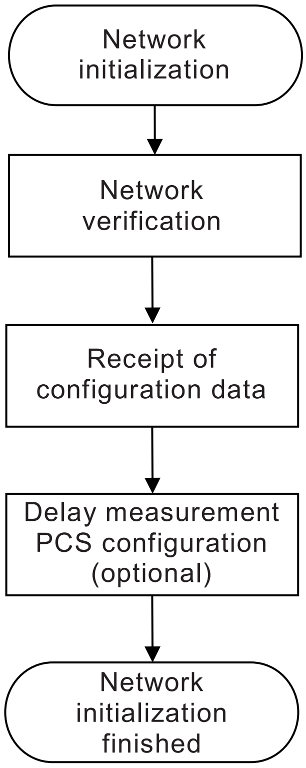


Figure 12 – Initialization sequence ordinary device

7.1.8 Precise clock synchronization (PCS)

7.1.8.1 Overview

NMPM handles the exchange of clock management data and commands between DLS-user and MSC-MTP PM. The clock synchronization services are based on MSC-MTP. NMPM combines or extracts DLPDUs according to the protocol specified within this standard and forwards the service requests to MSC-MTP and service responses to the DLS-user.

NMPM handles the protocol behavior for the delay measurement service for root devices and ordinary devices. The procedural sequences of this service within the Type 22 RTFL communication system are specified in Figure 13.

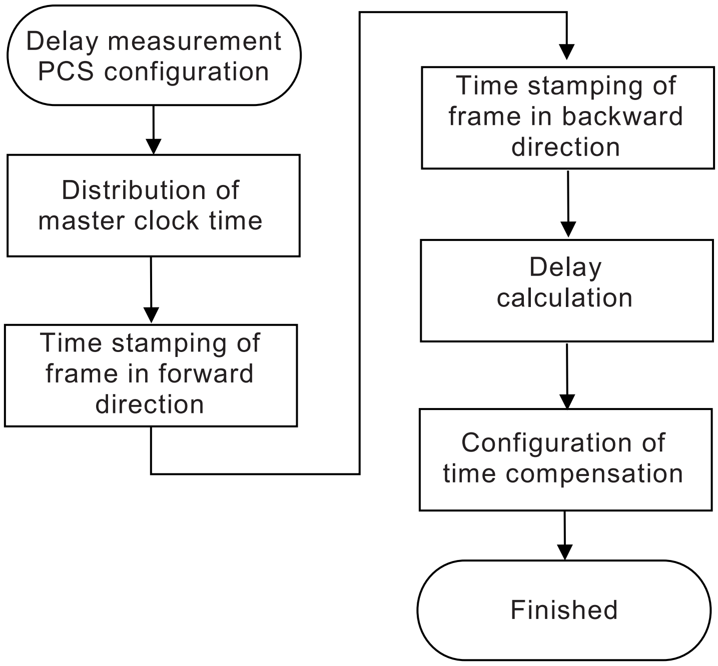


Figure 13 – PCS configuration sequence

7.1.8.2 Delay measurement sequence

Figure 14 shows the principles of delay measurement.

T_{SMC} (of the master clock) and T_{Fx} (of the various ordinary device clocks) refer to the receive time of a DLPDU in forward direction. T_{RMC} (of the master clock) and T_{Bx} (of the various ordinary device clocks) refer to the receive time of the same DLPDU in backward direction.

Each point in time is exactly determined by TSU. The compensation in time for each device is calculated according to the Formulas (1), (2) and (3). This model assumes a symmetric connection between all devices.

NOTE T_{SMC} is called send time master clock because a master clock sends the time value of the receipt of the MSCL DLPDU in which the reference time is inserted.

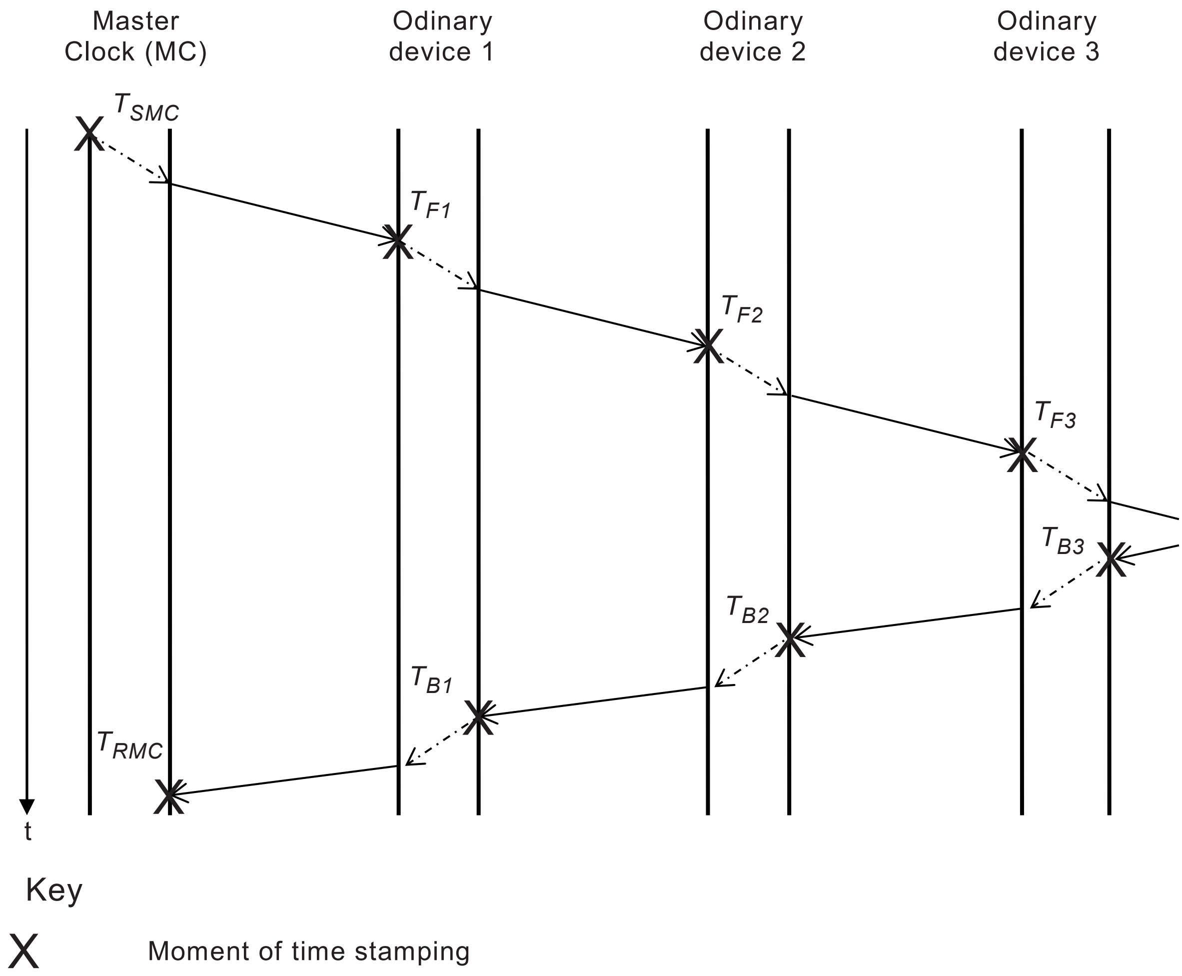


Figure 14 – Delay measurement principle

The compensation in time is calculated according to Formula (1), (2) and (3).

$$\Delta T_{MC} = T_{RMC} - T_{SMC} \qquad (1)$$

$$\Delta T_{ODx} = T_{Bx} - T_{Fx} \qquad (2)$$

$$T_{CompODx} = \frac{1}{2}\left(\Delta T_{MC} - \Delta T_{ODx}\right) \qquad (3)$$

where

T_{Fx}	is the receive time in forward direction for ordinary device x;
T_{Bx}	is the receive time in backward direction for ordinary device x;
T_{SMC}	is the send time master clock;
T_{RMC}	is the receive time master clock;
$T_{CompODx}$	is the compensation time of ordinary device x;

ΔT_{MC} is the difference between T_{RMC} and T_{SMC};

ΔT_{ODx} is the difference between T_{Bx} and T_{Fx}.

7.2 RTFN device protocol machines

7.2.1 Overview

Figure 15 depicts the general protocol machine structure within a Type 22 RTFN device by showing its protocol machines and their interaction.

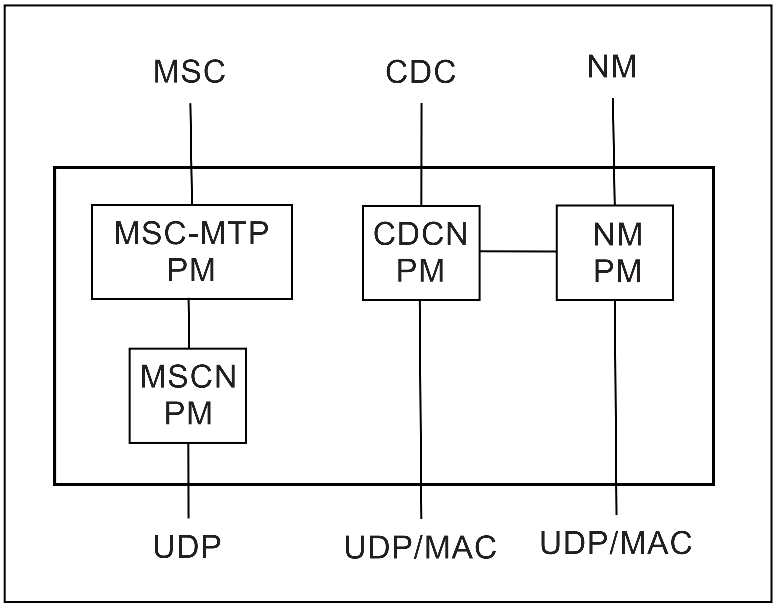


Figure 15 – Overview RTFN device protocol machines

7.2.2 Cyclic data channel network protocol machine (CDCNPM)

CDCN protocol machine is responsible for the exchange of process data objects between DLS-user and UDP/MAC. The CDCNPM combines or extracts process data objects according to the CDCN protocol specified within this standard. It forwards the service requests and responses according to the configuration of the RTFN device to the corresponding MAC services as specified in ISO/IEC 8802-3 or UDP services as specified in IETF RFC 768 and to the DLS-user. The network management protocol machine forwards the connection configuration data to the CDCNPM.

7.2.3 Message channel network protocol machine (MSCNPM)

MSCN protocol machine handles the exchange of acyclic message data between MSC-MTP PM and UDP. The MSCNPM combines or extracts MSC DLPDU data objects according to the MSCN protocol specified within this standard and forwards the service requests and responses to the MSC-MTP PM. The MSC services are directly forwarded to the appropriate UDP services as specified in IETF RFC 768.

7.2.4 Message channel message transfer protocol protocol machine (MSC-MTP PM)

As specified in 7.3.

7.2.5 Net management protocol machine (NMPM)

7.2.5.1 Overview

Network management procedures are functionally processed in response to network management service requests submitted by the DLS-user and events caused by the network. NM protocol machine handles the exchange of layer management data and commands between DLS-user and UDP/MAC. The NMPM combines or extracts communication management DLPDUs according to the protocol specified within this standard and forwards the service requests and responses to the DLS-user.

NMPM handles the protocol behavior for the RTFN scan network read service of a Type 22 RTFN network and implements the behavior as specified in 7.2.5.2. Furthermore, the procedural sequences of the RTFN connection management service used to commence CDCN communication within Type 22 RTFN communication system as specified in 7.2.5.3 and the protocol behavior for subscriber monitoring as specified in 7.2.5.4 are handled by NMPM.

7.2.5.2 RTFN scan network read

The RTFN scan network read allows to explore a Type 22 RTFN network. This is necessary for network diagnosis. An IP and a MAC broadcast is send out. Each RTFN device which receives this request responds with a reply.

7.2.5.3 CDCN Connection setup and release

CDCN connections utilize a publisher/subscriber mechanism. Publishers are configured which data packets they need to provide. Subscribers send an RTFNCS.request to indicate publishers the interest in particular process data objects. Publishers derive out the request the need for one or multiple DLPDUs sent to a subscriber for a dedicated connection. In case of a request, they send a response to acknowledge the connection establishment and start with cyclic sending. A subscriber sends an RTFNCR.request to indicate a publisher a subscriber-originated connection release. Figure 16 illustrates the connection establishment, data transfer and connection release phase for a CDCN connection.

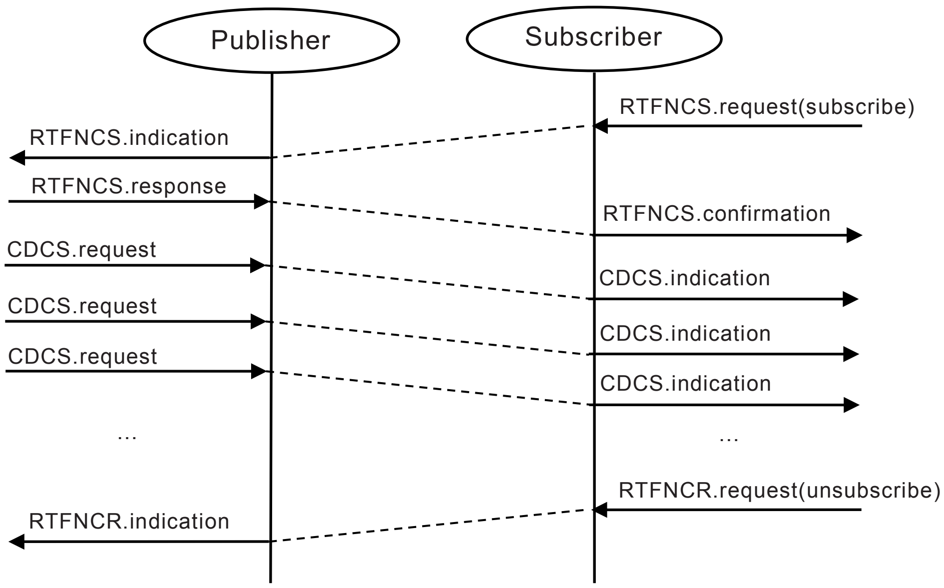


Figure 16 – CDCN connection setup and release

A publisher sends a RTFNCR.request to participating subscribers to indicate unpublished process data object. This procedure describes a publisher-originated connection release procedure. Figure 17 illustrates the appropriate sequence.

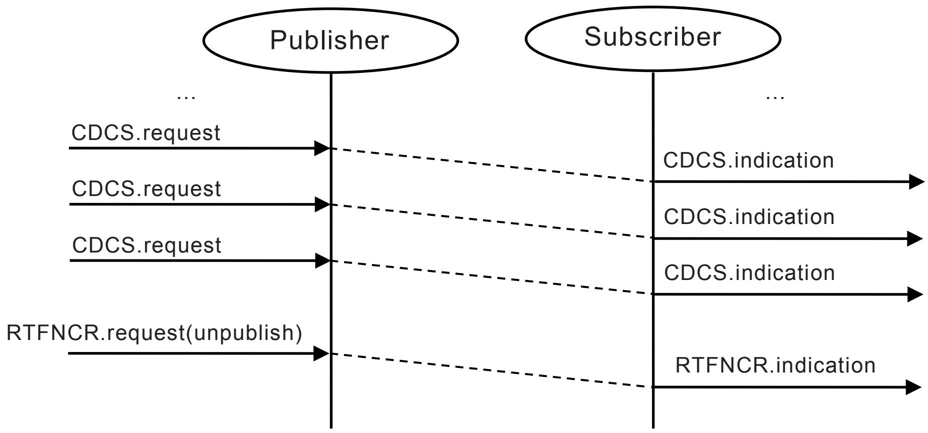


Figure 17 – CDCN unpulish data

7.2.5.4 CDCN Subscriber still alive

The net management has the task to monitor the presence of active process data subscribers. Each process data publisher maintains its currently active subscribers. A Type 22 RTFN device acting as a subscriber of process data objects sends CDCN connection still alive DLPDUs as specified in 5.5.4 in a cyclic manner. The cycle time is configuration dependent.

7.3 Message channel – Message transfer protocol (MSC-MTP)

7.3.1 Overview

The message channel message transfer protocol (MSC-MTP) is a protocol which utilizes the Type 22 message channel (MSC) for acyclic data exchange. It offers its user a reliable data exchange in applying segmentation, flow control and acknowledgement mechanisms for received data. To optimize the usage of available bandwidth, the acknowledgement mechanism follows a data volume driven approach.

7.3.2 MSC-MTP PM

7.3.2.1 Overview

MSC-MTP protocol machine is responsible for sequencing and confirmation of acyclic message exchange utilizing MSCL or MSCN.

Typically, MSC-MTP sends an initialization message to the destination device proposing a handle for the communication session. The destination device responds by confirming the handle and advises the maximum segment size (MSS) it can currently process. If several communication sessions exist between correlated participants, the handles associated with the appropriate communication relationship will be different.

The sender transfers data segments not to exceed MSS, together with the handle and an acknowledgement number. The acknowledgement number indicates the number of data octets sent including the actual segment.

The destination device acknowledges the receipt of segments by returning acknowledgement numbers. This is not done directly but when a pre-configured number of octets has been received since the last acknowledgement or a gap was detected in the data stream. The MSS can be reset/changed with each acknowledgement. The initialization message and the last segment are always acknowledged.

The source device expects acknowledgement of the sent segments inside a particular timeout and after a preconfigured amount of sent data. If this acknowledgement fails to arrive, the unconfirmed packets are resent.

The maximum number of send attempts can be configured. The transmission ends after sending the defined last segment and its acknowledgement by the destination or by an abort which can be sent at any time by one of the devices. If the transfer has failed (abort, timeout), DL-user is notified of this by the appropriate error message.

If the data volume is small enough to allow direct data transfer, the data is transferred in a special initialization message. This must also be the case if the destination address is a broadcast address. The source device defines whether acknowledgment by the destination device is expected or not. This is for example necessary in case of broadcast messages. Otherwise the destination will send an acknowledgement DLPDU if it is able to receive the message.

7.3.2.2 Segmented data transfer sequence

Figure 18 depicts the general sequence of segmented data transfer using MSC-MTP.

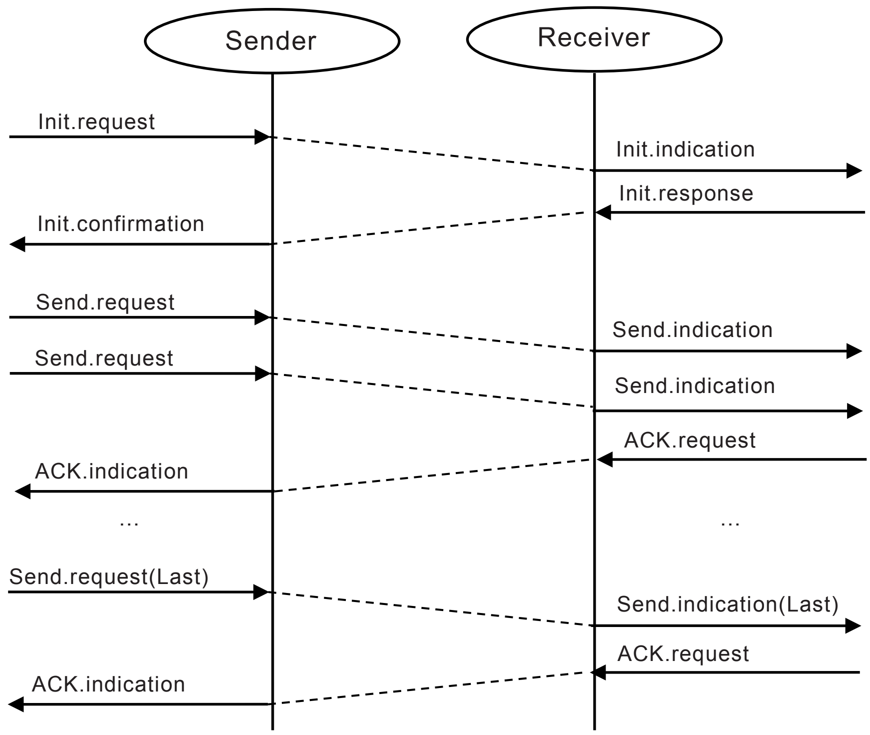


Figure 18 – Segmentation sequence

7.3.2.3 Expedited data transfer sequence

Figure 19 depicts the sequence of an expedited data transfer using MSC-MTP. The connection set-up an release phase are combined.

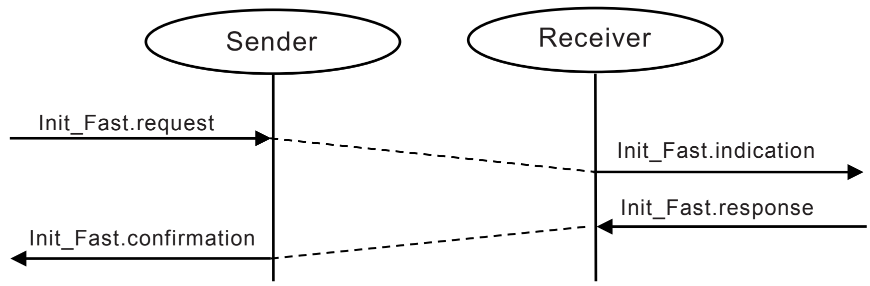


Figure 19 – Expedited transfer sequence

7.3.2.4 Toggling from expedited transfer to segmented transfer sequence

Figure 20 depicts the sequence of a data transfer requested as expedited transfer by the sender but accepted as segmented data transfer by the receiver using MSC-MTP.

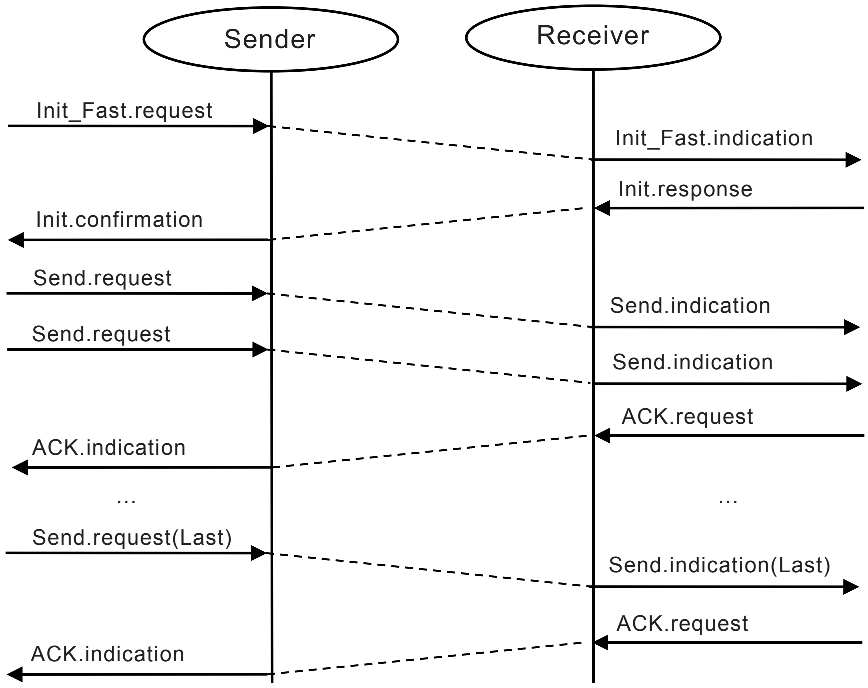


Figure 20 – Toggling from expedited transfer to segmented transfer

7.3.2.5 Transfer without Acknowledgement

Figure 21 depicts the sequence of a segmented data transfer (broad- or multicast) without Acknowledgement using MSC-MTP.

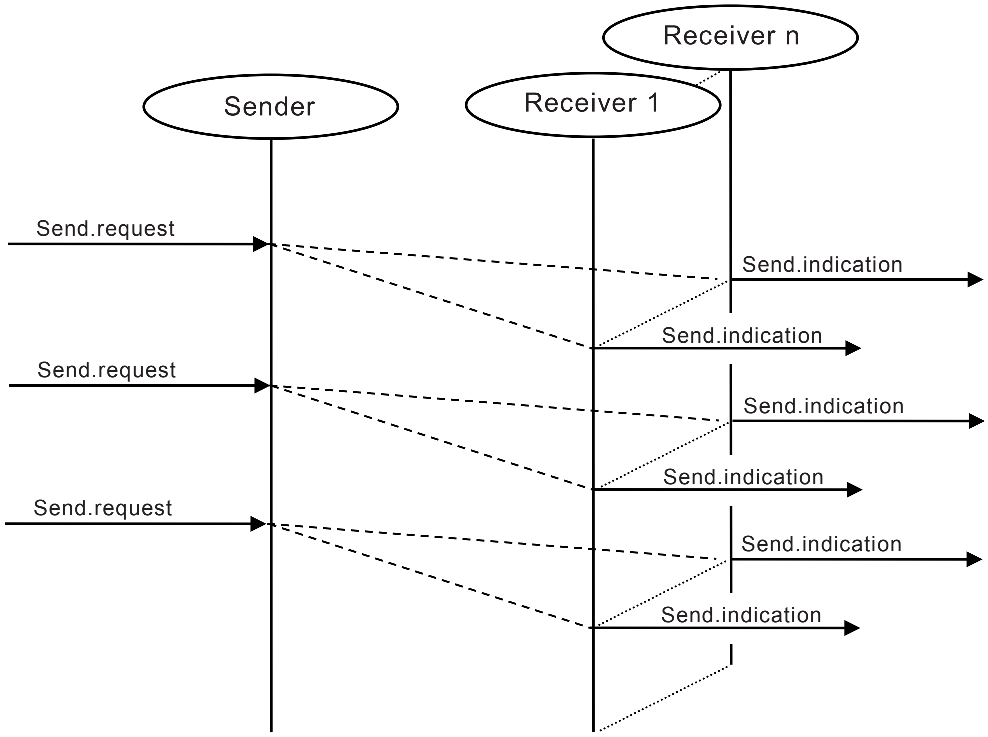


Figure 21 – Segmentation sequence for broad- or multicast message without Acknowledgement

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