



BSI Standards Publication

Industrial communication networks - Fieldbus specifications

Part 4-12: Data-link layer protocol specification - Type 12 elements

National foreword

This British Standard is the UK implementation of EN IEC 61158-4-12:2019. It is identical to IEC 61158-4-12:2019. It supersedes BS EN 61158-4-12:2014, which will be withdrawn on 23 May 2022.

The UK participation in its preparation was entrusted to Technical Committee GEL/65/3, Industrial communications: process measurement and control, including fieldbus.

A list of organizations represented on this committee can be obtained on request to its secretary.

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

© The British Standards Institution 2019
Published by BSI Standards Limited 2019

ISBN 978 0 539 04851 3

ICS 35.100.20; 25.040.40; 35.110

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2019.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

English Version

Industrial communication networks - Fieldbus specifications -
Part 4-12: Data-link layer protocol specification - Type 12
elements
(IEC 61158-4-12:2019)

Réseaux de communication industriels - Spécifications des
bus de terrain - Partie 4-12: Spécification du protocole de la
couche liaison de données - Éléments de type 12
(IEC 61158-4-12:2019)

Industrielle Kommunikationsnetze - Feldbusse - Teil 4-12:
Protokollspezifikation des Data Link Layer
(Sicherheitsschicht) - Typ 12-Elemente
(IEC 61158-4-12:2019)

This European Standard was approved by CENELEC on 2019-05-23. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 65C/946/FDIS, future edition 4 of IEC 61158-4-12, 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 IEC 61158-4-12:2019.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2020-02-23
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2022-05-23

This document supersedes EN 61158-4-12:2014.

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

Endorsement notice

The text of the International Standard IEC 61158-4-12:2019 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 61131-2	NOTE Harmonized as EN 61131-2
IEC 61131-3	NOTE Harmonized as EN 61131-3
IEC 61158-1	NOTE Harmonized as EN 61158-1
IEC 61158-2:2014	NOTE Harmonized as EN 61158-2:2014 (not modified)
IEC 61158-5-12:2019	NOTE Harmonized as EN IEC 61158-5-12:2019 (not modified)
IEC 61158-6-12	NOTE Harmonized as EN 61158-6-12
IEC 61784-1	NOTE Harmonized as EN 61784-1
IEC 61784-2	NOTE Harmonized as EN 61784-2

Annex ZA

(normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 Where 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.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61158-3-12	2019	Industrial communication networks - Fieldbus specifications - Part 3-12: Data- link layer service definition - Type 12 elements	-EN IEC 61158-3-12	2019
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 9899	-	Information technology - Programming- languages - C		-
ISO/IEC 10731	-	Information technology - Open Systems- Interconnection - Basic Reference Model - Conventions for the definition of OSI services		-
ISO/IEC/IEEE 8802-- 3		Standard for Ethernet	-	-
IEEE Std 802.1Q	-	IEEE Standard for Local and Metropolitan- Area Networks – Bridges and bridged networks		-
IETF RFC 768	-	User Datagram Protocol	-	-
IETF RFC 791	-	Internet protocol DARPA internet program- protocol specification		-

This page deliberately left blank

CONTENTS

FOREWORD.....	8
INTRODUCTION.....	10
1 Scope.....	11
1.1 General.....	11
1.2 Specifications	11
1.3 Procedures	11
1.4 Applicability	11
1.5 Conformance	11
2 Normative references	12
3 Terms, definitions, symbols, abbreviations and conventions	12
3.1 Reference model terms and definitions	12
3.2 Service convention terms and definitions	13
3.3 Common terms and definitions	14
3.4 Additional Type 12 definitions	14
3.5 Common symbols and abbreviations	17
3.6 Additional Type 12 symbols and abbreviations	18
3.7 Conventions.....	19
3.7.1 General concept	19
3.7.2 Abstract syntax conventions	19
3.7.3 Convention for the encoding of reserved bits and octets	21
3.7.4 Conventions for the common coding s of specific field octets	21
3.7.5 State machine conventions	22
4 Overview of the DL-protocol	24
4.1 Operating principle.....	24
4.2 Topology.....	24
4.3 Frame processing principles	24
4.4 Data-link layer overview	25
4.5 Error detection overview	26
4.6 Node reference model.....	26
4.6.1 Mapping onto OSI basic reference model	26
4.6.2 Data-link Layer features	27
4.7 Operation overview	27
4.7.1 Relation to ISO/IEC/IEEE 8802-3.....	27
4.7.2 Frame structure	27
5 Frame structure	28
5.1 Frame coding principles	28
5.2 Data types and encoding rules	28
5.2.1 General description of data types and encoding rules	28
5.2.2 Transfer syntax for bit sequences	28
5.2.3 Unsigned Integer	29
5.2.4 Signed Integer	30
5.2.5 Octet String	30
5.2.6 Visible String	30
5.3 Ethernet DLPDU structure.....	31
5.3.1 Type 12 frame inside an Ethernet frame	31
5.3.2 Type 12 frame inside a UDP datagram	31

5.3.3	Type 12 frame structure.....	33
5.4	Type 12 DLPDU structure	33
5.4.1	Read	33
5.4.2	Write	38
5.4.3	Read write	43
5.4.4	Attributes access	50
5.5	Network variable structure	50
5.6	Type 12 mailbox structure	51
6	Attributes.....	52
6.1	Management.....	52
6.1.1	DL Information.....	52
6.1.2	Station address	56
6.1.3	DL control.....	57
6.1.4	DL status	59
6.1.5	DLS-user specific registers.....	62
6.1.6	Event parameter.....	63
6.2	Statistics.....	68
6.2.1	RX error counter.....	68
6.2.2	Lost link counter	69
6.2.3	Additional counter.....	70
6.3	Watchdogs.....	71
6.3.1	Watchdog divider.....	71
6.3.2	DLS-user watchdog	72
6.3.3	Sync manager watchdog.....	72
6.3.4	Sync manager watchdog status	73
6.3.5	Watchdog counter.....	74
6.4	Slave information interface	74
6.4.1	Slave information interface area	74
6.4.2	Slave information interface access	74
6.4.3	Slave information interface control/status	75
6.4.4	Slave information interface address	77
6.4.5	Slave information interface data	78
6.5	Media independent interface (MII).....	78
6.5.1	MII control/status	78
6.5.2	MII address	80
6.5.3	MII data	81
6.5.4	MII access	81
6.6	Fieldbus memory management unit (FMMU)	82
6.6.1	General	82
6.6.2	FMMU attributes	83
6.7	Sync manager.....	85
6.7.1	Sync manager overview.....	85
6.7.2	Sync Manager Attributes.....	88
6.8	Distributed clock	91
6.8.1	General	91
6.8.2	Delay measurement.....	91
6.8.3	Local time parameter	92
6.8.4	DL-user time parameter	92
6.8.5	DC attributes	

7	DL-user memory	95
7.1	Overview	95
7.2	Mailbox access type.....	95
7.2.1	Mailbox transfer.....	95
7.2.2	Write access from master	95
7.2.3	Read access from master	97
7.3	Buffered access type	98
7.3.1	Write access from master	98
7.3.2	Read access from master	98
8	Type 12: FDL protocol state machines.....	99
8.1	Overview of slave DL state machines.....	99
8.2	State machine description.....	100
8.2.1	Port state machine (PSM).....	100
8.2.2	PDU handler state machine (DHSM).....	100
8.2.3	Sync manager state machine (SYSM).....	101
8.2.4	Resilient mailbox state machine (RMSM).....	101
8.2.5	SII state machine (SIISM).....	101
8.2.6	MII state machine (MIISM).....	105
8.2.7	DC state machine (DCSM).....	105
Annex A (informative) Type 12: Additional specifications on DL-Protocol state machines		108
A.1	DHSM.....	108
A.1.1	Primitive definitions	108
A.1.2	State machine description	109
A.1.3	DHSM table	110
A.1.4	Functions.....	125
A.2	SYSM	126
A.2.1	Primitive definition	126
A.2.2	State machine description	127
A.2.3	Local variables	128
A.2.4	State table nomenclature.....	128
A.2.5	SYSM table	128
A.2.6	Functions.....	138
A.3	RMSM.....	138
A.3.1	Primitive definitions	138
A.3.2	State machine description	139
A.3.3	Local variables	139
A.3.4	RMSM table.....	139
A.3.5	Functions.....	141
Bibliography.....		142
Figure 1 – Type description example		20
Figure 2 – Common structure of specific fields.....		21
Figure 3 – Frame structure.....		25
Figure 4 – Mapping of data in a frame.....		26
Figure 5 – Slave node reference model.....		27
Figure 6 – Type 12 PDUs embedded in Ethernet frame.....		28
Figure 7 – Type 12 PDUs embedded in UDP/IP		28

Figure 8 – DL information type description	54
Figure 9 – Address type description	56
Figure 10 – DL control type description	58
Figure 11 – DL status type description	61
Figure 12 – Successful write sequence to DL-user control register	62
Figure 13 – Successful read sequence to the DL-user status register	63
Figure 14 – RX error counter type description	69
Figure 15 – Lost link counter type description	70
Figure 16 – Additional counter type description	71
Figure 17 – Watchdog divider type description	72
Figure 18 – DLS-user Watchdog divider type description	72
Figure 19 – Sync manager watchdog type description	73
Figure 20 – Sync manager watchdog status type description	73
Figure 21 – Watchdog counter type description	74
Figure 22 – Slave information interface access type description	74
Figure 23 – Slave information interface control/status type description	76
Figure 24 – Slave information interface address type description	78
Figure 25 – Slave information interface data type description	78
Figure 26 – MII control/status type description	79
Figure 27 – MII address type description	81
Figure 28 – MII data type description	81
Figure 29 – MII access type description	82
Figure 30 – FMMU mapping example	83
Figure 31 – FMMU entity type description	84
Figure 32 – SyncM mailbox interaction	86
Figure 33 – SyncM buffer allocation	86
Figure 34 – SyncM buffer interaction	87
Figure 35 – Handling of write/read toggle with read mailbox	87
Figure 36 – Sync manager channel type description	89
Figure 37 – Distributed clock local time parameter type description	93
Figure 38 – Successful write sequence to mailbox	96
Figure 39 – Bad write sequence to mailbox	96
Figure 40 – Successful read sequence to mailbox	97
Figure 41 – Bad read sequence to mailbox	97
Figure 42 – Successful write sequence to buffer	98
Figure 43 – Successful read sequence to buffer	99
Figure 44 – Structuring of the protocol machines of an slave	100
Figure 45 – Slave information interface read operation	102
Figure 46 – Slave information interface write operation	103
Figure 47 – Slave information interface reload operation	104
Figure 48 – Distributed clock	106
Figure 49 – Delay measurement sequence	107

Table 1 – PDU element description example	20
Table 2 – Example attribute description	21
Table 3 – State machine description elements	23
Table 4 – Description of state machine elements	23
Table 5 – Conventions used in state machines	23
Table 6 – Transfer Syntax for bit sequences	29
Table 7 – Transfer syntax for data type Unsignedn	29
Table 8 – Transfer syntax for data type Integern	30
Table 9 – Type 12 frame inside an Ethernet frame	31
Table 10 – Type 12 frame inside an UDP PDU	32
Table 11 – Type 12 frame structure containing Type 12 PDUs	33
Table 12 – Type 12 frame structure containing network variables	33
Table 13 – Type 12 frame structure containing mailbox	33
Table 14 – Auto increment physical read (APRD)	34
Table 15 – Configured address physical read (FPRD)	35
Table 16 – Broadcast read (BRD)	36
Table 17 – Logical read (LRD)	37
Table 18 – Auto Increment physical write (APWR)	38
Table 19 – Configured address physical write (FPWR)	39
Table 20 – Broadcast write (BWR)	41
Table 21 – Logical write (LWR)	42
Table 22 – Auto increment physical read write (APRW)	43
Table 23 – Configured address physical read write (FPRW)	44
Table 24 – Broadcast read write (BRW)	45
Table 25 – Logical read write (LRW)	47
Table 26 – Auto increment physical read multiple write (ARMW)	48
Table 27 – Configured address physical read multiple write (FRMW)	49
Table 28 – Network variable	50
Table 29 – Mailbox	51
Table 30 – Error Reply Service Data	52
Table 31 – DL information	54
Table 32 – Configured station address	57
Table 33 – DL control	58
Table 34 – DL status	61
Table 35 – DLS-user specific registers	63
Table 36 – DLS-user event	65
Table 37 – DLS-user event mask	66
Table 38 – External event	67
Table 39 – External event mask	68
Table 40 – RX error counter	69
Table 41 – Lost link counter	70
Table 42 – Additional counter	71
Table 43 – Watchdog divider	72

Table 44 – DLS-user watchdog	72
Table 45 – Sync manager channel watchdog	73
Table 46 – Sync manager watchdog Status	73
Table 47 – Watchdog counter	74
Table 48 – Slave information interface access	75
Table 49 – Slave information interface control/status	76
Table 50 – Slave information interface address.....	78
Table 51 – Slave information interface data	78
Table 52 – MII control/status.....	80
Table 53 – MII address	81
Table 54 – MII data.....	81
Table 55 – MII access.....	82
Table 56 – Fieldbus memory management unit (FMMU) entity	84
Table 57 – Fieldbus memory management unit (FMMU).....	85
Table 58 – Sync manager channel	90
Table 59 – Sync manager Structure	91
Table 60 – Distributed clock local time parameter	93
Table 61 – Distributed clock DLS-user parameter	94
Table A.1 – Primitives issued by DHSM to PSM.....	108
Table A.2 – Primitives issued by PSM to DHSM.....	108
Table A.3 – Parameters used with primitives exchanged between DHSM and PSM.....	108
Table A.4 – Identifier for the octets of a Ethernet frame	109
Table A.5 – DHSM state table.....	111
Table A.6 – DHSM function table	126
Table A.7 – Primitives issued by SYSM to DHSM.....	126
Table A.8 – Primitives issued by DHSM to SYSM.....	127
Table A.9 – Primitives issued by DL-User to SYSM.....	127
Table A.10 – Primitives issued by SYSM to DL-User.....	127
Table A.11 – Parameters used with primitives exchanged between SYSM and DHSM	127
Table A.12 – SYSM state table	129
Table A.13 – SYSM function table.....	138
Table A.14 – Primitives issued by RMSM to SYSM	138
Table A.15 – Primitives issued by SYSM to RMSM	139
Table A.16 – Parameters used with primitives exchanged between RMSM and SYSM	139
Table A.17 – RMSM state table.....	140
Table A.18 – RMSM function table.....	141

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**INDUSTRIAL COMMUNICATION NETWORKS –
FIELDBUS SPECIFICATIONS –****Part 4-12: Data-link layer protocol specification –
Type 12 elements**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

Attention is drawn to the fact that the use of the associated protocol type is restricted by its 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 layer protocol type to be used with other layer protocols of the same type, or in other type combinations explicitly authorized by its intellectual-property-right holders.

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

International Standard IEC 61158-4-12 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This fourth edition cancels and replaces the third edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- technical corrections and editorial improvements for clarification.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
65C/946/FDIS	65C/955/RVD

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

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

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

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

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

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document 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 document is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer data-link entities (DLEs) at the time of communication. These rules for communication are intended to provide a sound basis for development in order to serve a variety of purposes:

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

This document is concerned, in particular, with the communication and interworking of sensors, effectors and other automation devices. By using this document 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 12 elements and possibly other types given as follows:

EP 1 590 927 B1	[BE] Koppler für ein Netzwerk mit Ringtopologie und ein auf Ethernet basierten Netzwerk
EP 1 789 857 B1	[BE] Datenübertragungsverfahren und automatisierungssystem zum Einsatz eines solchen Datenübertragungsverfahrens
EP 2 137 893 B1	[BE] Paketvermittlungsvorrichtung und lokales Kommunikationsnetz mit einer solchen Paketvermittlungsvorrichtung
EP 1 456 722 B1	[BE] Datenübertragungsverfahren, seriellcs Bussystem und Anschalteinheit für einen passiven Busteilnehmer

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

The holder of these patent rights has assured the IEC that he/she is willing to negotiate licences 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 holder of these patent rights is registered with IEC. Information may be obtained from:

[BE]: Beckhoff Automation GmbH
Eiserstraße 5
33415 Verl,
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 databases of patents relevant to their standards. Users are encouraged to consult the databases for the most up to date information concerning patents.

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-12: Data-link layer protocol specification – Type 12 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, 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 document specifies

- a) procedures for the transfer of data and control information from one data-link user entity to one or more user entity;
- b) the structure of the DLPDUs used for the transfer of data and control information by the protocol of this document, and their representation as physical interface data units.

1.3 Procedures

The procedures are defined in terms of

- a) the interactions between DL-entities (DLEs) through the exchange of 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 the MAC services of ISO/IEC/IEEE 8802-3.

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 reference model, 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 document also specifies conformance requirements for systems implementing these procedures. This part of this document does not contain tests to demonstrate compliance with such requirements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 61158-3-12:2019, *Industrial communication networks – Fieldbus specifications – Part 3-12: Data-link layer service definition – Type 12 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/IEEE 8802-3, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet*

ISO/IEC 9899, *Information technology – Programming Languages – C*

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

IEEE Std 802.1Q, *IEEE Standard for Local and Metropolitan Area Networks – Bridges and Bridged Networks*, available at <http://www.ieee.org> [viewed 2018-09-11]

IETF RFC 768, *User Datagram Protocol (UDP)*, available at <http://www.ietf.org> [viewed 2018-09-11]

IETF RFC 791, *Internet protocol DARPA internet program protocol specification*, available at <http://www.ietf.org> [viewed 2018-09-11]

3 Terms, definitions, symbols, abbreviations and conventions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 Reference model terms and definitions

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

3.1.1	DL-duplex-transmission	[ISO/IEC 7498-1]
3.1.2	DL-protocol	[ISO/IEC 7498-1]
3.1.3	DL-protocol-data-unit	[ISO/IEC 7498-1]
3.1.4	(N)-entity DL-entity Ph-entity	[ISO/IEC 7498-1]
3.1.5	(N)-interface-data-unit DL-service-data-unit (N=2) Ph-interface-data-unit (N=1)	[ISO/IEC 7498-1]
3.1.6	(N)-layer DL-layer (N=2) Ph-layer (N=1)	[ISO/IEC 7498-1]
3.1.7	(N)-service DL-service (N=2) Ph-service (N=1)	[ISO/IEC 7498-1]
3.1.8	(N)-service-access-point DL-service-access-point (N=2) Ph-service-access-point (N=1)	[ISO/IEC 7498-1]
3.1.9	(N)-service-access-point-address DL-service-access-point-address (N=2) Ph-service-access-point-address (N=1)	[ISO/IEC 7498-1]
3.1.10	peer-entities	[ISO/IEC 7498-1]
3.1.11	Ph-interface-data	[ISO/IEC 7498-1]
3.1.12	primitive name	[ISO/IEC 7498-3]
3.1.13	reassembling	[ISO/IEC 7498-1]
3.1.14	recombining	[ISO/IEC 7498-1]
3.1.15	reset	[ISO/IEC 7498-1]
3.1.16	routing	[ISO/IEC 7498-1]
3.1.17	segmenting	[ISO/IEC 7498-1]
3.1.18	sequencing	[ISO/IEC 7498-1]
3.1.19	splitting	[ISO/IEC 7498-1]
3.1.20	systems-management	[ISO/IEC 7498-1]

3.2 Service convention terms and definitions

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

- 3.2.1 asymmetrical service**
- 3.2.2 confirm (primitive);
requestor.deliver (primitive)**
- 3.2.3 deliver (primitive)**
- 3.2.4 DL-service-primitive;
primitive**
- 3.2.5 DL-service-provider**
- 3.2.6 DL-service-user**
- 3.2.7 indication (primitive)
acceptor.deliver (primitive)**
- 3.2.8 request (primitive);
requestor.submit (primitive)**
- 3.2.9 requestor**
- 3.2.10 response (primitive);
acceptor.submit (primitive)**
- 3.2.11 submit (primitive)**
- 3.2.12 symmetrical service**

3.3 Common terms and definitions

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

For the purposes of this document, the following definitions also apply:

3.3.1 frame

denigrated synonym for DLPDU

3.3.2 group DL-address

DL-address that potentially designates more than one DLSAP within the extended link

Note 1 to entry: A single DL-entity may have multiple group DL-addresses associated with a single DLSAP.

Note 2 to entry: A single DL-entity also may have a single group DL-address associated with more than one DLSAP.

3.3.3 node

single DL-entity as it appears on one local link

3.3.4 receiving DLS-user

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

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

3.3.5 sending DLS-user

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

3.4 Additional Type 12 definitions

3.4.1 application

function or data structure for which data is consumed or produced

[SOURCE: IEC 61158-5-12, 3.3.1]

3.4.2

application objects

multiple object classes that manage and provide a run time exchange of messages across the network and within the network device

3.4.3

basic slave

slave device that supports only physical addressing of data

3.4.4

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.

3.4.5

client

<object> object which uses the services of another (server) object to perform a task

3.4.6

client

<message> initiator of a message to which a server reacts

3.4.7

connection

logical binding between two application objects within the same or different devices

3.4.8

cyclic

events which repeat in a regular and repetitive manner

3.4.9

cyclic redundancy check

CRC

residual value computed from an array of data and used as a representative signature for the array

3.4.10

data

generic term used to refer to any information carried over a Fieldbus

3.4.11

data consistency

means for coherent transmission and access of the input- or output-data object between and within client and server

3.4.12

device

physical entity connected to the fieldbus composed of at least one communication element (the network element) and which may have a control element and/or a final element (transducer, actuator, etc.)

[SOURCE: IEC 61158-2, 3.1.13]

3.4.13

distributed clocks

method to synchronize slaves and maintain a global time base

3.4.14

error

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

3.4.15

event

instance of a change of conditions

3.4.16

fieldbus memory management unit

function that establishes one or several correspondences between logical addresses and physical memory

3.4.17

fieldbus memory management unit entity

single element of the fieldbus memory management unit: one correspondence between a coherent logical address space and a coherent physical memory location

3.4.18

full slave

slave device that supports both physical and logical addressing of data

3.4.19

interface

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

3.4.20

master

device that controls the data transfer on the network and initiates the media access of the slaves by sending messages and that constitutes the interface to the control system

3.4.21

mapping

correspondence between two objects in that way that one object is part of the other object

3.4.22

medium

cable, optical fibre, or other means by which communication signals are transmitted between two or more points

Note 1 to entry: "media" is used as the plural of medium.

3.4.23

message

ordered series of octets intended to convey information

Note 1 to entry: Normally used to convey information between peers at the application layer.

3.4.24

network

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

3.4.25**node**

end-point of a link in a network or a point at which two or more links meet

[SOURCE: IEC 61158-2, 3.1.31, modified – wording adjustment]

3.4.26**object**

abstract representation of a particular component within a device

Note 1 to entry: An object can be

- 1) an abstract representation of the capabilities of a device. Objects can be composed of any or all of the following components:
 - a) data (information which changes with time);
 - b) configuration (parameters for behavior);
 - c) methods (things that can be done using data and configuration).
- 2) a collection of related data (in the form of variables) and methods (procedures) for operating on that data that have clearly defined interface and behavior.

3.4.27**process data**

data object containing application objects designated to be transferred cyclically or acyclically for the purpose of processing

3.4.28**server**

object which provides services to another (client) object

3.4.29**service**

operation or function than an object and/or object class performs upon request from another object and/or object class

3.4.30**slave**

DL-entity accessing the medium only after being initiated by the preceding slave or the master

3.4.31**Sync manager**

collection of control elements to coordinate access to concurrently used objects

3.4.32**Sync manager channel**

single control elements to coordinate access to concurrently used objects

3.4.33**switch**

MAC bridge as defined in IEEE 802.1D

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.

DL-	Data-link layer (as a prefix)
DLC	DL-connection
DLCEP	DL-connection-end-point
DLE	DL-entity (the local active instance of the data-link layer)
DLL	DL-layer
DLPCI	DL-protocol-control-information
DLPDU	DL-protocol-data-unit
DLM	DL-management
DLME	DL-management Entity (the local active instance of DL-management)
DLMS	DL-management Service
DLS	DL-service
DLSAP	DL-service-access-point
DLSDU	DL-service-data-unit
FIFO	First-in first-out (queuing method)
OSI	Open systems interconnection
Ph-	Physical layer (as a prefix)
PhE	Ph-entity (the local active instance of the physical layer)
PhL	Ph-layer
QoS	Quality of service

3.6 Additional Type 12 symbols and abbreviations

AL	Application layer
AoE	Automation Device Specification (ADS) over Type 12
APRD	Auto increment physical read
APRW	Auto increment physical read write
APWR	Auto increment physical write
ARMW	Auto increment physical read multiple write
BRD	Broadcast read
BRW	Broadcast read write
BWR	Broadcast write
CAN	Controller area network
CoE	CAN application protocol over Type 12 services
CSMA/CD	Carrier sense multiple access with collision detection
DC	Distributed clocks
DSCM	DC state machine
DHSM	(DL) PDU handler state machine
Type 12	Prefix for DL services and protocols
E ² PROM	Electrically erasable programmable read only memory
EoE	Ethernet tunneled over Type 12 services
ESC	Type 12 slave controller
FCS	frame check sequence
FMMU	Fieldbus memory management unit

FoE	File access with Type 12 services
FPRD	Configured address physical read
FPRW	Configured address physical read write
FPWR	Configured address physical write
FRMW	Configured address physical read multiple write
HDR	Header
ID	Identifier
IP	Internet protocol
LAN	Local area network
LRD	Logical memory read
LRW	Logical memory read write
LWR	Logical memory write
MAC	Media access control
MDI	Media dependent interface (specified in ISO/IEC/IEEE 8802-3)
MDX	Mailbox data exchange
MII	Media independent interface (specified in ISO/IEC/IEEE 8802-3)
PDI	Physical device interface (a set of elements that allows access to DL services from the DLS-user)
PDO	Process data object
PHY	Physical layer device (specified in ISO/IEC/IEEE 8802-3)
RAM	Random access memory
RMSM	Resilient mailbox state machine
Rx	Receive
SDO	Service data object
SII	Slave information interface
SIISM	SII state machine
SyncM	Synchronization manager
SYSM	Sync manager state machine
TCP	Transmission control protocol
Tx	Transmit
UDP	User datagram protocol
WKC	Working counter

3.7 Conventions

3.7.1 General concept

The services are specified in IEC 61158-3-12. The service specification defines the services that are provided by the Type 12 DL. The mapping of these services to ISO/IEC/IEEE 8802-3 is described in this document.

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

3.7.2 Abstract syntax conventions

The DL syntax elements related to PDU structure are described as shown in the example of 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 – PDU element description example

Frame part	Data Field	Data Type	Value/Description
Type 12 xxx	CMD	Unsigned8	0x01
	IDX	Unsigned8	Index
	ADP	Unsigned16	Auto Increment Address
	ADO	Unsigned16	Physical Memory Address
	LEN	Unsigned11	Length of data of YYY in octets
	Reserved	Unsigned4	0x00
	NEXT	Unsigned1	0: last Type 12 PDU 1: Type 12 PDU follows
	IRQ	Unsigned16	Reserved for future use
	YYY		next element
	WKC	Unsigned16	Working Counter

The attribute types are described in C language notations (ISO/IEC 9899) as shown in Figure 1. BYTE and WORD are elements of type unsigned char and unsigned short. DWORD is a four octet double word.

```
typedef struct
{
    Unsigned8      Type;
    Unsigned8      Revision;
    Unsigned16     Build;
    Unsigned8      NoOfSuppFmmuChannels;
    Unsigned8      NoOfSuppSyncManChannels;
    Unsigned8      RamSize;
    Unsigned8      Reserved1;
    unsigned       FmmuBitOperationNotSupp: 1;
    unsigned       Reserved2: 7;
    unsigned       Reserved3: 8;
} TDLINFORMATION;
```

Figure 1 – Type description example

The attributes itself are described in a form as shown in Table 2.

Parameter describes a single element of the attribute.

Physical address denotes the location in physical address space.

Data Type denotes the type of this element.

Access type Type 12 DL/PDI shows the access right to this element. R means read access right, W means write access right. If neither Type 12 DL nor PDI has write access, this variable will be initialised and maintained by DL itself.

Value/Description contains the constant value and/or the meaning of the parameter.

Table 2 – Example attribute description

Parameter	Physical Address	Data Type	Access type	Access Type PDI	Value/Description
State	0x0120	Unsigned4	RW	R	0x01: Init Request 0x02: Pre-Operational Request 0x03: Bootstrap Mode Request 0x04: Safe Operational Request 0x08: Operational Request
Acknowledge	0x0120	Unsigned1	RW	R	0: no acknowledge 1 acknowledge (shall be a positive edge)
Reserved	0x0120	Unsigned3	RW	R	0x00
Application Specific	0x0121	Unsigned8	RW	R	

3.7.3 Convention for the encoding of reserved bits and octets

The term "reserved" may be used to describe bits in octets or whole octets. All bits or octets that are reserved should be set to zero at the sending side and shall not be tested at the receiving side unless it is explicitly stated or if the reserved bits or octets are checked by a state machine.

The term "reserved" may also be used to indicate that certain values within the range of a parameter are reserved for future extensions. In this case the reserved values should not be used at the sending side and shall not be tested at the receiving side except it is explicitly stated or if the reserved values are checked by a state machine.

3.7.4 Conventions for the common coding s of specific field octets

DLSDUs may contain specific fields that carry information in a primitive and condensed way. These fields shall be coded in the order according to Figure 2.

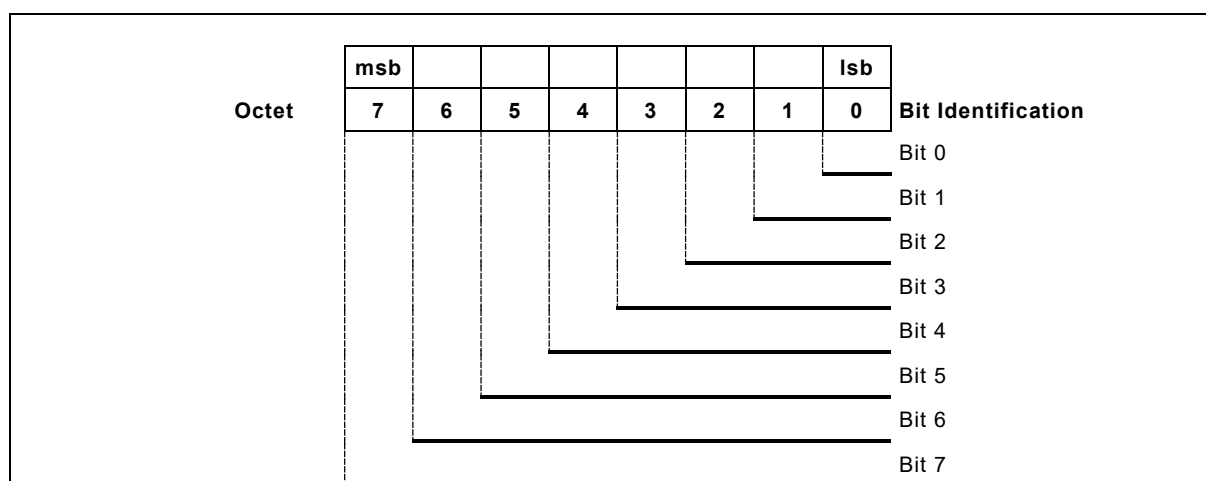


Figure 2 – Common structure of specific fields

Bits may be grouped as group of bits. Each bit or group of bits shall be addressed by its Bit Identification (e.g. Bit 0, Bit 1 to 4). The position within the octet shall be according to the figure above. Alias names may be used for each bit or group of bits or they may be marked as reserved. The grouping of individual bits shall be in ascending order without gaps. The values for a group of bits may be represented as binary, decimal or hexadecimal values. This value shall only be valid for the grouped bits and can only represent the whole octet if all 8 bits are grouped. Decimal or hexadecimal values shall be transferred in binary values so that the bit with the highest number of the group represents the msb concerning the grouped bits.

EXAMPLE Description and relation for the specific field octet

Bit 0: reserved.

Bit 1-3: Reason_Code The decimal value 2 for the Reason_Code means general error.

Bit 4-7: shall always set to one.

The octet that is constructed according to the description above looks as follows:

(msb) Bit 7 = 1,

Bit 6 = 1,

Bit 5 = 1,

Bit 4 = 1,

Bit 3 = 0,

Bit 2 = 1,

Bit 1 = 0,

(lsb) Bit 0 = 0.

This bit combination has an octet value representation of 0xf4.

3.7.5 State machine conventions

The protocol sequences are described by means of State Machines.

In state diagrams states are represented as boxes state transitions are shown as arrows. Names of states and transitions of the state diagram correspond to the names in the textual listing of the state transitions.

The textual listing of the state transitions is structured as follows, see also Table 3.

- The first column contains the name of the transition.
- The second column in define the current state.
- The third column contains an optional event followed by Conditions starting with a “/” as first line character and finally followed by the actions starting with a “=>” as first line character.
- The last column contains the next state.

If the event occurs and the conditions are fulfilled the transition fires, i.e. the actions are executed and the next state is entered.

The layout of a Machine description is shown in Table 3. The meaning of the elements of a State Machine Description are shown in Table 4.

Table 3 – State machine description elements

#	Current state	Event /Condition => Action	Next state

Table 4 – Description of state machine elements

Description element	Meaning
Current state	Name of the given states.
Next state	
#	Name or number of the state transition.
Event	Name or description of the event.
/Condition	Boolean expression. The preceding “\” is not part of the condition.
=> Action	List of assignments and service or function invocations. The preceding “=>” is not part of the action.

The conventions used in the state machines are shown in Table 5.

Table 5 – Conventions used in state machines

Convention	Meaning
=	Value of an item on the left is replaced by value of an item on the right. If an item on the right is a parameter, it comes from the primitive shown as an input event.
axx	A parameter name if a is a letter. EXAMPLE Identifier = reason means value of a 'reason' parameter is assigned to a parameter called 'Identifier.'
"xxx"	Indicates fixed visible string. EXAMPLE Identifier = "abc" means value "abc" is assigned to a parameter named 'Identifier.'
nnn	if all elements are digits, the item represents a numerical constant shown in decimal representation
0xnn	if all elements nn are digits, the item represents a numerical constant shown in hexadecimal representation
==	A logical condition to indicate an item on the left is equal to an item on the right.
<	A logical condition to indicate an item on the left is less than the item on the right.
>	A logical condition to indicate an item on the left is greater than the item on the right.
!=	A logical condition to indicate an item on the left is not equal to an item on the right.
&&	Logical "AND"
	Logical "OR"
!	Logical "NOT"
+ – * /	Arithmetic operators
;	Separator of expressions

Readers are strongly recommended to refer to the subclauses for the attribute definitions, the local functions, and the FDL-PDU definitions to understand protocol machines. It is assumed that readers have sufficient knowledge of these definitions and they are used without further explanations.

Further constructs as defined in C language notation (ISO/IEC 9899) can be used to describe conditions and actions.

4 Overview of the DL-protocol

4.1 Operating principle

Type 12 DL is a Real Time Ethernet technology that aims to maximize the utilization of the full duplex Ethernet bandwidth. Medium access control employs the Master/Slave principle, where the master node (typically the control system) sends the Ethernet frames to the slave nodes, which extract data from and insert data into these frames.

From an Ethernet point of view, a Type 12 segment is a single Ethernet device, which receives and sends ISO/IEC/IEEE 8802-3 Ethernet frames. However, this Ethernet device is not limited to a single Ethernet controller with downstream microprocessor, but may consist of a large number of Type 12 slave devices. These process the incoming frames directly and extract the relevant user data, or insert data and transfer the frame to the next slave device. The last Type 12 slave device within the segment sends the fully processed frame back, so that it is returned by the first slave device to the master as response frame.

This procedure utilizes the full duplex mode of Ethernet: both communication directions are operated independently. Direct communication without switch between a master device and a Type 12 segment consisting of one or several slave devices may be established.

4.2 Topology

The topology of a communication system is one of the crucial factors for the successful application in automation. The topology has significant influence on the cabling effort, diagnostic features, redundancy options and hot-plug-and-play features.

The star topology commonly used for Ethernet leads to enhanced cabling effort and infrastructure costs. Especially for automation applications a line or tree topology is preferable.

The slave node arrangement represents an open ring bus. At the open end, the master device sends frames, either directly or via Ethernet switches, and receives them at the other end after they have been processed. All frames are relayed from the first node to the next ones. The last node returns the PDU back to the master. Utilizing the full duplex capabilities of Ethernet, the resulting topology is a physical line.

Branches, which in principle are possible anywhere, can be used to enhance the line structure into a tree structure from. A tree structure supports very simple wiring; individual branches, for example, can branch into control cabinets or machine modules, while the main line runs from one module to the next.

4.3 Frame processing principles

In order to achieve maximum performance, the Ethernet frames should be processed directly “on the fly”. If it is implemented this way, the slave node recognizes relevant commands and executes them accordingly while the frames are already passed on.

NOTE 1 Type 12 DL can be implemented using standard Ethernet controllers without direct processing. The influence of the forwarding mechanism implementation on communication performance is detailed in the profile parts.

The nodes have an addressable memory that can be accessed with read or write services, either each node consecutively or several nodes simultaneously. Several Type 12 PDUs can be embedded within an Ethernet frame, each PDU addressing a cohesive data section. As shown in Figure 3, the Type 12 PDUs are either transported:

- a) directly in the data area of the Ethernet frame,
- b) within the data section of a UDP datagram transported via IP.

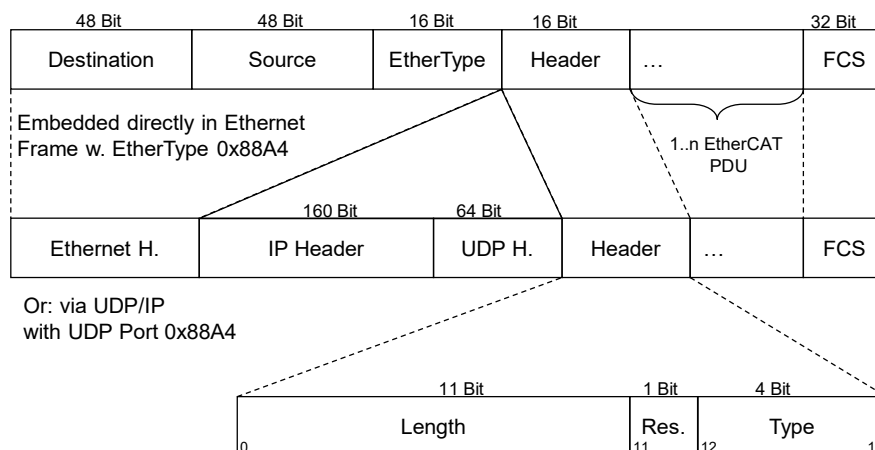


Figure 3 – Frame structure

Variant a) is limited to one Ethernet subnet, since associated frames are not relayed by routers. For machine control applications this usually does not represent a constraint. Multiple Type 12 segments can be connected to one or several switches. The Ethernet MAC address of the first node within the segment is used for addressing the Type 12 segment.

NOTE 2 Further addressing details are given in the data-link layer service definition (see IEC 61158-3-12).

Variant b) via UDP/IP generates a slightly larger overhead (IP and UDP header), but for less time-critical applications such as building automation it allows using IP routing. On the master side any standard UDP/IP implementation can be used.

4.4 Data-link layer overview

Several nodes can be addressed individually via a single Ethernet frame carrying several Type 12 PDUs. The Type 12 PDUs are packed without gaps. The frame is terminated with the last Type 12 PDU, unless the frame size is less than 64 octets, in which case the frame is padded to 64 octets in length.

Compared with one frame per node this leads to a better utilization of the Ethernet bandwidth. However, for e.g. a 2 channel digital input node with just 2 bit of user data, the overhead of a single Type 12 PDU is still excessive.

Therefore the slave nodes may also support logical address mapping. The process data can be inserted anywhere within a logical address space. If a Type 12 PDU is sent that contains read or write services for a certain process image area located at the corresponding logical address, instead of addressing a particular node, the nodes insert the data at or extract the data from the right place within the process data, as noted in Figure 4.

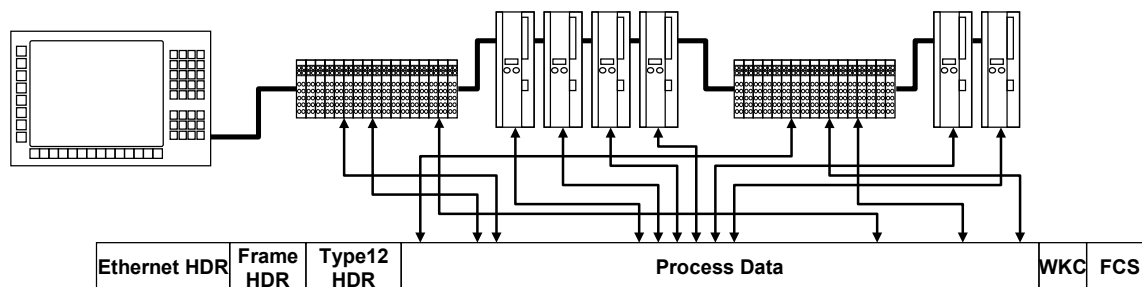


Figure 4 – Mapping of data in a frame

All other nodes that also detect an address match with the process image also insert their data, so that many nodes can be addressed simultaneously with a single Type 12 PDU. The master can assemble completely sorted logical process images via a single Type 12 PDU. Additional mapping is no longer required in the master, so that the process data can be assigned directly to the different control tasks. Each task can create its own process image and exchange it within its own timeframe. The physical order of the nodes is completely arbitrary and is only relevant during the first initialization phase.

The logical address space is 2^{32} Bytes = 4 GByte. Type 12 DL can be considered to be a serial backplane for automation systems that enables connection to distributed process data for both large and very small automation devices. Using a standard Ethernet controller and a standard Ethernet cable, a very large number of I/O channels without practical restrictions on the distribution can be connected to automation devices, which can be accessed with high bandwidth, minimum delay and near-optimum usable data rate. At the same time, devices such as fieldbus scanners can be connected as well, thus preserving existing technologies and standards.

4.5 Error detection overview

Type 12 DL checks by the Ethernet frame check sequence (FCS) whether a frame was transmitted correctly. Since one or several slaves modify the frame during the transfer, the FCS is recalculated by each slave. If a slave detects a checksum error, the slave does not repair the FCS but flags the master by incrementing the error counter, so that a fault can be located precisely.

When reading data from or writing data to a Type 12 PDU, the addressed slave increments a working counter (WKC) positioned at the end of each Type 12 PDU. Analyzing the working counter allows the master to check if the expected number of nodes has processed the corresponding Type 12 PDU.

4.6 Node reference model

4.6.1 Mapping onto OSI basic reference model

Type 12 DL is described using the principles, methodology and model of ISO/IEC 7498 Information processing systems — Open Systems Interconnection — Basic Reference Model (OSI). The OSI model provides a layered approach to communications standards, whereby the layers can be developed and modified independently. The Type 12 DL specification defines functionality from top to bottom of a full OSI stack, and some functions for the users of the stack. Functions of the intermediate OSI layers, layers 3 – 6, are consolidated into either the Type 12 DL data-link layer or the Type 12 DL Application layer. Likewise, features common to users of the Fieldbus Application layer may be provided by the Type 12 DL Application layer to simplify user operation, as noted in Figure 5.

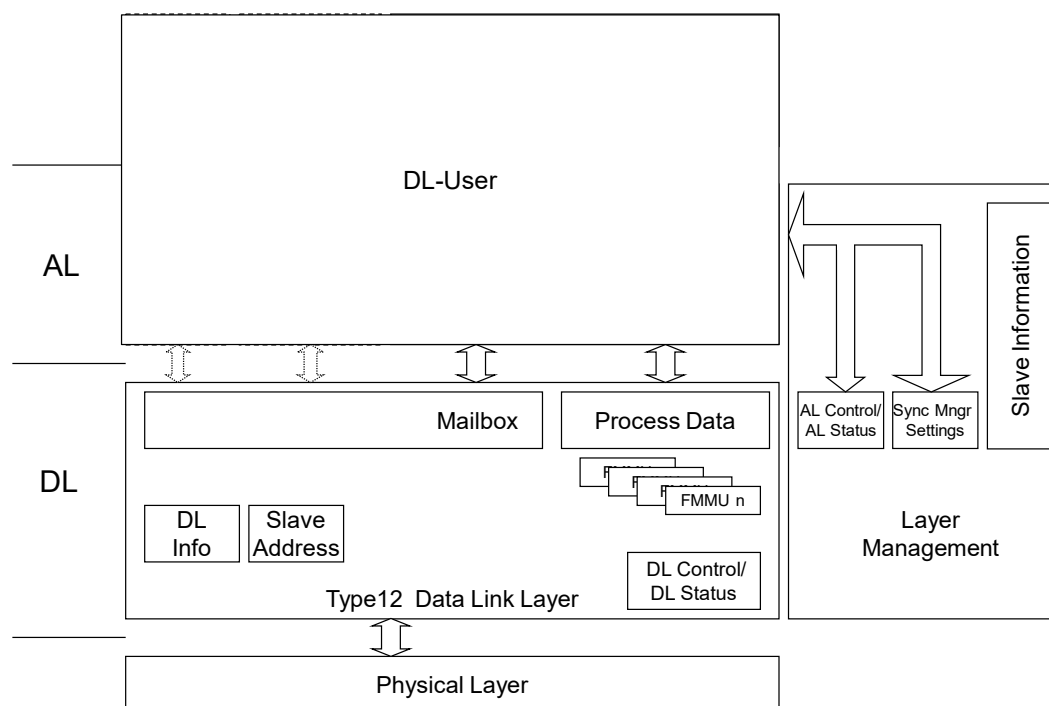


Figure 5 – Slave node reference model

4.6.2 Data-link Layer features

The data link layer provides basic time critical support for data communications among devices connected via Type 12 DL. The term “time-critical” is used to describe applications having a time-window, within which one or more specified actions are required to be completed with some defined level of certainty. Failure to complete specified actions within the time window risks failure of the applications requesting the actions, with attendant risk to equipment, plant and possibly human life.

The data link layer has the task to compute, compare and generate the frame check sequence and provide communications by extracting data from and/or including data into the Ethernet frame. This is done depending on the data link layer parameters which are stored at pre-defined memory locations. The application data is made available to the application layer in physical memory, either in a mailbox configuration or within the process data section.

4.7 Operation overview

4.7.1 Relation to ISO/IEC/IEEE 8802-3

This part specifies data link layer services in addition to those specified in ISO/IEC/IEEE 8802-3.

4.7.2 Frame structure

A Type 12 Ethernet frame contains one or several Type 12 PDUs (as shown in Figure 6), each addressing individual devices and/or memory areas. The Type 12 frame is recognized by the combination of the EtherType 0x88A4¹ and the corresponding Type 12 frame header or, when transported via UDP/IP according to IETF RFC 791/IETF RFC 768 (as shown in Figure 7) by the Destination UDP port 34980=0x88A4² and the Type 12 frame header. Fragmentation of IP

¹ The EtherType 0x88A4 was assigned for Type 12 (EtherCAT) by the IEEE Registration Authority.

² The UDP Port 34980 was assigned for Type 12 (EtherCAT) by the Internet Assigned Numbers Authority (IANA).

packets will be ignored. The UDP checksum shall be set to 0 by Slaves and could be ignored. No check on IP type of service, IP header checksum, IP packet length and UDP length is required.

Each Type 12 PDU consists of a Type 12 header, the data area and a subsequent counter area (working counter), which is incremented by all nodes that were addressed by the Type 12 PDU and have exchanged associated data.

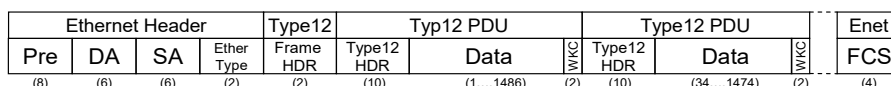


Figure 6 – Type 12 PDUs embedded in Ethernet frame

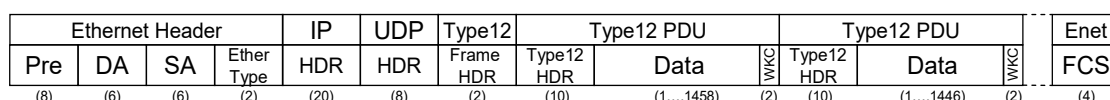


Figure 7 – Type 12 PDUs embedded in UDP/IP

5 Frame structure

5.1 Frame coding principles

Type 12 DL uses a ISO/IEC/IEEE 8802-3 Ethernet frame structure for transporting Type 12 PDUs. The PDUs may alternatively be sent via UDP/IP. The Type 12 specific protocol parts are identical in both cases.

5.2 Data types and encoding rules

5.2.1 General description of data types and encoding rules

To be able to exchange meaningful data, the format of this data and its meaning have to be known by the producer and consumer(s). 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 representations. Values are represented as bit sequences. Bit sequences are transferred in sequences of octets (bytes). For numerical data types the encoding is little endian style as shown in Table 6.

The data types and encoding rules shall be valid for the DL services and protocols as well as for the AL services and protocols specified. The encoding rules for the Ethernet frame are specified in ISO/IEC/IEEE 8802-3. The DLSDU of Ethernet 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 12 DL a bit sequence is reordered into a sequence of octets. Hexadecimal notation is used for octets as specified in ISO/IEC 9899. Let $b = b_0...b_{n-1}$ be a bit sequence. Denote k a non-negative integer such that $8(k - 1) < n \leq 8k$. Then b is transferred in k octets assembled as shown in Table 6. The bits b_i , $i \geq n$ of the highest 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 (transmission order within an octet is determined by ISO/IEC/IEEE 8802-3):

$$b_7, b_6, \dots, b_0, b_{15}, \dots, b_8, \dots$$

Table 6 – Transfer Syntax for bit sequences

Octet number	1.	2.	k.
	$b_7 \dots b_0$	$b_{15} \dots b_8$	$b_{8k-1} \dots b_{8k-8}$

EXAMPLE

Bit 9	...	Bit 0
10b	0001b	1100b
0x2	0x1	0xC
		= 0x21C

The bit sequence $b = b_0 \dots b_9 = 0011\ 1000\ 01_b$ represents an Unsigned10 with the value 0x21C and is transferred in two octets: First 0x1C and then 0x02.

5.2.3 Unsigned Integer

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

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

is assigned the value

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

The bit sequence starts on the left with the least significant byte.

EXAMPLE The value 266 = 0x10A with data type Unsigned16 is transferred in two octets, first 0x0A and then 0x01.

The Unsigned n data types are transferred as specified in Table 7. Unsigned data types as Unsigned1 to Unsigned7 and Unsigned 9 to Unsigned15 will be used too. In this case the next element will start at the first free bit position as denoted in 3.7.1.

Table 7 – Transfer syntax for data type Unsigned n

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

5.2.4 Signed Integer

Data of basic data type Integer n 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

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

is assigned the value

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

and, performing two's complement arithmetic,

$$\text{Integer}_n(b) = -\text{Integer}_n(\text{^}b) - 1 \text{ if } b_{n-1} = 1$$

NOTE The bit sequence starts on the left with the least significant bit.

EXAMPLE The value $-266 = 0xFEF6$ with data type Integer16 is transferred in two octets, first 0xF6 and then 0xFE.

The Integer n data types are transferred as specified in Table 8. Integer data types as Integer1 to Integer7 and Integer9 to Integer15 will be used too. In this case the next element will start at the first free bit position as denoted in 3.7.1.

Table 8 – Transfer syntax for data type Integer n

Octet number	1.	2.	3.	4.	5.	6.	7.	8.
Integer8	b7..b0							
Integer16	b7..b0	b15..b8						
Integer32	b7..b0	b15..b8	b23..b16	b31..b24				
Integer64	b7..b0	b15..b8	b23..b16	b31..b24	b39..b32	b47..b40	b55..b48	b63..b56

5.2.5 Octet String

The data type OctetString $length$ is defined below; $length$ is the length of the octet string.

ARRAY [length] OF Unsigned8 OctetString $length$

5.2.6 Visible String

The data type VisibleString $length$ is defined below. The admissible values of data of type *VISIBLE_CHAR* are 0_h and the range from 0x20 to 0x7E. The data are interpreted as 7-bit coded characters. $length$ is the length of the visible string.

Unsigned8 *VISIBLE_CHAR*

ARRAY [length] OF *VISIBLE_CHAR* VisibleString $length$

There is no 0x0 necessary to terminate the string.

5.3 Ethernet DLPDU structure

5.3.1 Type 12 frame inside an Ethernet frame

The frame structure consists of the following data entries as specified in Table 9.

Table 9 – Type 12 frame inside an Ethernet frame

Frame part	Data field	Data type	Value/description
Ethernet	Dest MAC	BYTE[6]	Destination MAC Address as specified in ISO/IEC/IEEE 8802-3
	Src MAC	BYTE[6]	Source MAC Address as specified in ISO/IEC/IEEE 8802-3
(optional)	VLAN Tag	BYTE[4]	0x81, 0x00 and two bytes Tag Control Information as specified in IEEE 802.1Q
	Ether Type	BYTE[2]	0x88, 0xA4 (Type 12)
	Type 12 frame		specified in 5.3.3
	Padding	BYTE[n]	shall be inserted if DL PDU is shorter than 64 octets as specified in ISO/IEC/IEEE 8802-3
Ethernet FCS	FCS	Unsigned32	Standard Ethernet Checksum coding as specified in ISO/IEC/IEEE 8802-3

5.3.2 Type 12 frame inside a UDP datagram

The frame structure in consists of the following data entries as specified in Table 10.

Table 10 – Type 12 frame inside an UDP PDU

Frame part	Data field	Data type	Value/description
Ethernet	Dest MAC	BYTE[6]	See Table 9
	Src MAC	BYTE[6]	See Table 9
	(optional) VLAN Tag	BYTE[4]	See Table 9
	Ether Type	BYTE[2]	0x08, 0x00 (IP)
IP	VersionHL	BYTE	0x45 (IP Version(4) header length (5*4 octets))
	Service	BYTE	0x00 (IP Type of service)
	TotalLength	Unsigned16	(IP total length of service) – not checked within Type 12 segment
	Identification	Unsigned16	(IP identification packet for fragmented service) – not checked within Type 12 segment
	Flags	BYTE	Should not be fragmented (IP flags – they will not be considered but a fragmentation of Type 12 frame will result in an error) – not checked within Type 12 segment
	Fragments	BYTE	Should be 0 (IP fragment number – fragmentation of Type 12 frame will result in an error) – not checked within Type 12 segment
	Ttl	BYTE	(IP time to live – only checked at routers) – not checked within Type 12 segment
	Protocol	BYTE	0x11 (IP sub-protocol – this value is reserved for UDP)
	Header checksum	Unsigned16	(IP header checksum) – not checked within Type 12 segment
	Source IP address	BYTE[4]	(IP source address of the originator) – not checked within Type 12 segment
	Destination IP address	BYTE[4]	(IP destination address of the target of the frame – within a Type 12 segment usually a multicast address as an individual address requires the Address Resolution Protocol ARP) – not checked within Type 12 segment
UDP	Src port	WORD	(UDP Source Port) – not checked within Type 12 segment
	Dest port	WORD	0x88A4 (UDP Destination Port)
	Length	WORD	(UDP length of frame)) – not checked within Type 12 segment
	Checksum	WORD	(UDP checksum of frame) – will be set to 0 for Type 12 frames but without checking
	Type 12 frame		specified in 5.3.3
	Ethernet Padding	BYTE[n]	shall be inserted if DL PDU is shorter than 64 octets as specified in ISO/IEC/IEEE 8802-3
Ethernet FCS	FCS	Unsigned32	Standard Ethernet Checksum coding as specified in ISO/IEC/IEEE 8802-3
NOTE 1 IP packet structure and coding requirements are as specified in IETF RFC 791.			
NOTE 2 The ordering of octets in multi-octet values is encoded differently in IETF protocols (see IETF RFC 768 and RFC 791) than it is within the Type 12 DL-protocol.			

5.3.3 Type 12 frame structure

The Type 12 frame structure shall consist one of the structures specified in Table 11, Table 12 and Table 13.

Table 11 – Type 12 frame structure containing Type 12 PDUs

Frame part	Data field	Data type	Value/description
Type 12 Frame	Length	Unsigned11	Length of this frame (minus 2 octets)
	Reserved	Unsigned1	0
	Type	Unsigned4	Protocol Type = Type 12 DLPDUs (0x01)
	Type 12 PDU 1		specified in 5.4
	...		specified in 5.4
	Type 12 PDU n		specified in 5.4

Table 12 – Type 12 frame structure containing network variables

Frame part	Data field	Data type	Value/description
Type 12 frame	Length	Unsigned11	Length of this frame (minus 2 octets)
	reserved	Unsigned1	0
	Type	Unsigned4	Protocol type = network variables (0x04)
Publisher header	PubID	BYTE[6]	Publisher ID
	CntNV	Unsigned16	Number of Network variables contained in this Type 12 frame
	CYC	Unsigned16	Cycle Number of the publisher side
	reserved	BYTE[2]	0x00, 0x00
	Network variable 1		Specified in 5.5
	...		Specified in 5.5
	Network variable n		Specified in 5.5

Table 13 – Type 12 frame structure containing mailbox

Frame part	Data field	Data type	Value/description
Type 12 frame	Length	Unsigned11	Length of this frame (minus 2 octets)
	reserved	Unsigned1	0
	Type	Unsigned4	Protocol type = mailbox (0x05)
	Mailbox		Specified in 5.6

5.4 Type 12 DLPDU structure

5.4.1 Read

5.4.1.1 Overview

With the read services a master reads data from register or memory of one or several slaves. The working counter shall be incremented by each slave if at least one of the addressed attributes is present.

5.4.1.2 Auto increment physical read (APRD)

The auto increment physical read (APRD) coding is specified in Table 14. Each slave increments the address ADP. The slave that receives an auto-increment address with value zero executes the requested read operation.

Table 14 – Auto increment physical read (APRD)

Frame part	Data field	Data type	Value/description
Type 12 PDU	CMD	Unsigned8	0x01 (command APRD)
	IDX	Unsigned8	Index
	ADP	WORD	Auto increment address
	ADO	WORD	Physical memory or register address
	LEN	Unsigned11	Length of the DATA data field
	reserved	Unsigned3	0x00
	C	Unsigned1	Circulating frame 0: Frame is not circulating, 1: Frame has circulated once
	NEXT	Unsigned1	0: last Type 12 PDU in Type 12 frame 1: Type 12 PDU in Type 12 frame follows
	IRQ	WORD	External event
	DATA	OctetString LEN	Data, structure as specified in 5.6, Clause 6 or by DLS-user
	WKC	WORD	Working counter

CMD

The parameter Command shall contain the service command.

IDX

The parameter Index is the local identifier in the master of the service and shall not be changed by the slave.

ADP

Each slave shall increment this parameter and the slave that receives this parameter with a value of zero shall perform the read access.

NOTE That means, the parameter contains the negative position of the slave in the logical loop beginning with 0 at the master side (e.g. -7 means that seven slaves are between the master and the addressed slave). At the confirmation this parameter contains the value of the request incremented by the number of transited slave devices.

ADO

This parameter shall contain the start address in the physical memory of the slave where the data to be read is stored

LEN

This parameter shall contain the size in octets of the data to be read.

C

This Parameter shall indicate that the frame has circulated in the network and shall not be forwarded.

NEXT

This parameter shall specify if there is another Type 12 PDU in the frame.

IRQ

This parameter shall contain the External event (see Table 38) masked by the External event mask (see Table 39).

DATA

This parameter shall contain the read data if the access is valid at the addressed slaves site. Otherwise the value send out with the request remains unchanged.

WKC

This parameter shall be incremented by one if the data was successfully read.

5.4.1.3 Configured address physical read (FPRD)

The configured address physical read (FPRD) coding is specified in Table 15.

Table 15 – Configured address physical read (FPRD)

Frame part	Data field	Data type	Value/description
Type 12 PDU	CMD	Unsigned8	0x04 (command FPRD)
	IDX	Unsigned8	Index
	ADP	WORD	Configured station address or configured station alias
	ADO	WORD	Physical memory or register address
	LEN	Unsigned11	Length of the DATA data field
	reserved	Unsigned3	0x00
	C	Unsigned1	Circulating frame 0: Frame is not circulating, 1: Frame has circulated once
	NEXT	Unsigned1	0: last Type 12 PDU in Type 12 frame 1: Type 12 PDU in Type 12 frame follows
	IRQ	WORD	External event
	DATA	OctetString LEN	Data, structure as specified in 5.6, Clause 6 or by DLS-user
	WKC	WORD	Working counter

CMD

The parameter Command shall contain the service command.

IDX

The parameter Index is the local identifier in the master of the service; it shall not be changed by the slave.

ADP

The slave which has the value of D_address as station address or station address alias shall execute a read action.

ADO

This parameter shall contain the start address in the physical memory of the slave where the data to be read is stored.

LEN

This parameter shall contain the size in octets of the data to be read.

C

This Parameter shall indicate that the frame has circulated in the network and shall not be forwarded.

NEXT

This parameter shall specify if there is another Type 12 PDU in the frame.

IRQ

This parameter shall contain the External event (see Table 38) masked by the External event mask (see Table 39).

DATA

This parameter shall contain the read data if the access is valid at the addressed slaves site. Otherwise the value send out with the request remains unchanged.

WKC

This parameter shall be incremented by one if the data was successfully read.

5.4.1.4 Broadcast read (BRD)

The broadcast read (BRD) coding is specified in Table 16.

Table 16 – Broadcast read (BRD)

Frame part	Data field	Data type	Value/description
Type 12 PDU	CMD	Unsigned8	0x07 (command BRD)
	IDX	Unsigned8	Index
	ADP	WORD	Parameter incremented by 1 at each station forwarding BRD PDU
	ADO	WORD	Physical memory or register address
	LEN	Unsigned11	Length of the DATA data field
	reserved	Unsigned3	0x00
	C	Unsigned1	Circulating frame 0: Frame is not circulating, 1: Frame has circulated once
	NEXT	Unsigned1	0: last Type 12 PDU in Type 12 frame 1: Type 12 PDU in Type 12 frame follows
	IRQ	WORD	External event
	DATA	OctetString LEN	Data, structure as specified in 5.6, Clause 6 or by DLS-user
	WKC	WORD	Working counter

CMD

The parameter Command shall contain the service command.

IDX

The parameter Index is the local identifier in the master of the service; it shall not be changed by the slave.

ADP

This parameter shall be incremented by one at each slave.

ADO

This parameter shall contain the start address in the physical memory where the data to be read is stored. Each slave who supports the requested physical memory area (physical memory address and length) shall respond to this service.

LEN

This parameter shall contain the size in octets of the data to be read.

C

This Parameter shall indicate that the frame has circulated in the network and shall not be forwarded.

NEXT

This parameter shall specify if there is another Type 12 PDU in the frame.

IRQ

This parameter shall contain the External event (see Table 38) masked by the External event mask (see Table 39).

DATA

This parameter shall contain the read data collected before entry or default values of the master. This parameter shall contain the result of the bitwise-OR operation between the parameter data of the request and the addressed data in the slave.

WKC

This parameter shall be incremented by one by all slaves which made the bitwise-OR of the requested data.

5.4.1.5 Logical read (LRD)

The logical read (LRD) coding is specified in Table 17. The slave copies only data to the parameter data that are mapped by an FMMU entity from the logical address space to a physical address.

Table 17 – Logical read (LRD)

Frame part	Data field	Data type	Value/description
Type 12 PDU	CMD	Unsigned8	0x0A (command LRD)
	IDX	Unsigned8	Index
	ADR	DWORD	Logical address
	LEN	Unsigned11	Length of the DATA data field
	reserved	Unsigned3	0x00
	C	Unsigned1	Circulating frame 0: Frame is not circulating, 1: Frame has circulated once
	NEXT	Unsigned1	0: last Type 12 PDU in Type 12 frame 1: Type 12 PDU in Type 12 frame follows
	IRQ	WORD	reserved for future use
	DATA	OctetString LEN	Data, structure as specified by DLS-user
	WKC	WORD	Working counter

CMD

The parameter Command shall contain the service command.

IDX

The parameter Index is the local identifier in the master of the service; it shall not be changed by the slave.

ADR

This parameter shall contain the start address in the logical memory where the data to be read is located. All slaves which have one or more address matches of the requested logical memory area (logical memory address and length) in their FMMU entities shall map the requested data to the data parameter as described by the FMMU entity settings and increment the working counter.

LEN

This parameter shall contain the size in octets of the data to be read.

C

This Parameter shall indicate that the frame has circulated in the network and shall not be forwarded.

NEXT

This parameter shall specify if there is another Type 12 PDU in the frame.

IRQ

This parameter shall contain the External event (see Table 38) masked by the External event mask (see Table 39).

DATA

On confirm this parameter specifies the data read from the device. Each slave which detects an address match of the requested logical memory area puts the data of the corresponding physical memory area in the correct part of this parameter.

WKC

This parameter shall be incremented by one by all slaves which detect an address match of the requested logical memory area.

5.4.2 Write**5.4.2.1 Overview**

With the write services a master writes data to register or memory of one or several slaves. The working counter is incremented if the addressed attribute is present and at least one part of the data can be written.

5.4.2.2 Auto increment physical write (APWR)

The auto increment physical write (APWR) coding is specified in Table 18. Each slave increments the address. The slave that receives a zero value at auto-increment address parameter will execute the requested write operation.

Table 18 – Auto Increment physical write (APWR)

Frame part	Data field	Data type	Value/description
Type 12 PDU	CMD	Unsigned8	0x02 (command APWR)
	IDX	Unsigned8	Index
	ADP	WORD	Auto increment address
	ADO	WORD	Physical memory or register address
	LEN	Unsigned11	Length of the DATA data field
	reserved	Unsigned3	0x00
	C	Unsigned1	Circulating frame 0: Frame is not circulating, 1: Frame has circulated once
	NEXT	Unsigned1	0: last Type 12 PDU in Type 12 frame 1: Type 12 PDU in Type 12 frame follows
	IRQ	WORD	External event
	DATA	OctetString LEN	Data, structure as specified in 5.6, Clause 6 or by DLS-user
	WKC	WORD	Working counter

CMD

The parameter Command shall contain the service command.

IDX

The parameter Index is the local identifier in the master of the service; it shall not be changed by the slave.

ADP

The slave will be addressed by its position in the segment. Each slave shall increment this parameter, the slave who receives the value zero of this parameter shall respond to this service.

NOTE That means, the parameter contains the negative position of the slave in the logical ring beginning with 0 at the master side (e.g. -7 means 7 slaves are between master and the addressed slave). At the confirmation this parameter contains the value of the request incremented by the number of transited slave devices.

ADO

This parameter shall contain the start address in the physical memory of the slave where the data to be written is stored.

LEN

This parameter shall contain the size in octets of the data to be written.

C

This Parameter shall indicate that the frame has circulated in the network and shall not be forwarded.

NEXT

This parameter shall specify if there is another Type 12 PDU in the frame.

IRQ

This parameter shall contain the External event (see Table 38) masked by the External event mask (see Table 39).

DATA

This parameter shall contain the data to be written.

WKC

This parameter shall be incremented by one if the data can be successfully written.

5.4.2.3 Configured address physical write (FPWR)

The configured address physical write (FPWR) coding is specified in Table 19.

Table 19 – Configured address physical write (FPWR)

Frame part	Data field	Data type	Value/description
Type 12 PDU	CMD	Unsigned8	0x05 (command FPWR)
	IDX	Unsigned8	Index
	ADP	WORD	Configured station address or configured station alias
	ADO	WORD	Physical memory or register address
	LEN	Unsigned11	Length of the DATA data field
	reserved	Unsigned3	0x00
	C	Unsigned1	Circulating frame 0: Frame is not circulating, 1: Frame has circulated once
	NEXT	Unsigned1	0: last Type 12 PDU in Type 12 frame 1: Type 12 PDU in Type 12 frame follows
	IRQ	WORD	External event
	DATA	OctetString LEN	Data, structure as specified in 5.6, Clause 6 or by DLS-user
	WKC	WORD	Working counter

CMD

The parameter Command shall contain the service command.

IDX

The parameter Index is the local identifier in the master of the service; it shall not be changed by the slave.

ADP

The slave which has the value of D_address as station address or station address alias shall execute a write action.

ADO

This parameter shall contain the start address in the physical memory of the slave where the data to be written is stored.

LEN

This parameter shall contain the size in octets of the data to be written.

C

This Parameter shall indicate that the frame has circulated in the network and shall not be forwarded.

NEXT

This parameter shall specify if there is another Type 12 PDU in the frame.

IRQ

This parameter shall contain the External event (see Table 38) masked by the External event mask (see Table 39).

DATA

This parameter shall contain the data to be written.

WKC

This parameter shall be incremented by one if the data was successfully written.

5.4.2.4 Broadcast write (BWR)

The broadcast write (BWR) coding is specified in Table 20.