

Digital data communication for measurement and control — Fieldbus for use in industrial control systems —

Part 4: Data link protocol specification

The European Standard EN 61158-4:2004 has the status of a
British Standard

ICS 25.040; 35.100; 35.240.50

National foreword

This British Standard is the official English language version of EN 61158-4:2004. It is identical with IEC 61158-4:2004. It, together with BS EN 61158-2:2004, BS EN 61158-3:2004, BS EN 61158-5:2004, BS EN 61158-6:2004 and BS EN 61784-1:2004, supersedes BS EN 50170:1997 and BS EN 50254:1999, which are withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AMT/7, Industrial communications: Process measurement and control, including fieldbus, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

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

Compliance with a British Standard does not of itself confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 8 September 2004

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 1096, an inside back cover and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments

© BSI 8 September 2004

ISBN 0 580 44291 8

EUROPEAN STANDARD

EN 61158-4

NORME EUROPÉENNE

EUROPÄISCHE NORM

July 2004

ICS 25.040; 35.100; 35.240.50

Partially supersedes EN 50170:1996 + A1:2002 + A2:1999 + A3:2002 and EN 50254:1998

English version

**Digital data communication for measurement and control -
Fieldbus for use in industrial control systems
Part 4: Data link protocol specification
(IEC 61158-4:2003 + corrigendum 2004)**

Communications numériques pour les
systèmes de mesure et de commande -
Bus de terrain utilisés dans les systèmes
de commande industriels
Partie 4: Spécification du protocole
de la couche de liaison de données
(CEI 61158-4:2003 + corrigendum 2004)

Digitale Datenkommunikation
in der Leittechnik -
Feldbus für industrielle Leitsysteme
Teil 4: Spezifikation des Protokolls
der Sicherungsschicht (Data Link Layer)
(IEC 61158-4:2003 + Corrigendum 2004)

This European Standard was approved by CENELEC on 2004-03-16. 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 Central Secretariat or to any CENELEC member.

This European Standard exists in one official version (English). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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

CENELEC

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

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

© 2004 CENELEC - All rights of exploitation in any form and by any means reserved worldwide for CENELEC members.

Ref. No. EN 61158-4:2004 E



Documents
Document Sharing Hub

Foreword

The text of the International Standard IEC 61158-4:2003, prepared by SC 65C, Digital communications, of IEC TC 65, Industrial-process measurement and control, was submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 61158-4 on 2004-03-16 with inclusion of the accepted future IEC corrigendum.

This European Standard, together with EN 61158-2:2004, EN 61158-3:2004, EN 61158-5:2004, EN 61158-6:2004 and EN 61784-1:2004, supersedes EN 50170:1996 + A1:2002 (+ corr. Aug. 2002) + A2:1999 + A3:2002 (+ corr. Aug. 2002) and EN 50254:1998.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2005-04-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2007-04-01

The International Electrotechnical Commission (IEC) and CENELEC draw attention to the fact that it is claimed that compliance with this document may involve the use of patents as follows, where the [xx] notation indicates the holder of the patent right:

Type 1 time synchronization and possibly other types:

JP Hei4-35096 [YC] Communication control method

Type 2 and possibly other types:

US 5,400,331	[AB]	Communication network interface with screeners for incoming messages
US, 5,471,461	[AB]	Digital communication network with a moderator station election process
US 5,491,531	[AB]	Media access controller with a shared class message delivery capability
US 5,493,571	[AB]	Apparatus and method for digital communications with improved delimiter detection
US 5,537,549	[AB]	Communication network with time coordinated station activity by time slot and periodic interval number
US 5,553,095	[AB]	Method and apparatus for exchanging different classes of data during different time intervals

Type 3 and possibly other types:

DE 36 43 979 C2	[SI]	Deterministisches Zugriffsverfahren nach dem Tokenprinzip für eine Datenübertragung
DE 36 43 979 A1	[SI]	Deterministisches Zugriffsverfahren nach dem Tokenprinzip für eine Datenübertragung

Type 8 and possibly other types:

DE 41 00 629 C1 [PxC] Steuer- und Datenübertragungsanlage

The IEC and CENELEC take no position concerning the evidence, validity and scope of these patent rights.

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

[AB]: Rockwell Technologies, LLC
Allen-Bradley Co, LLC
1201 So. Second Street
Milwaukee, WI 53204
USA
Attention: Intellectual Property Dept.

[PxC]: Phoenix Contact GmbH & Co. KG
Referat Patente / Patent Department
Postfach 1341
D-32819 Blomberg
Germany

[SI]: Siemens AG
Ludwig Winkel
Siemensallee 84
D-76181 Karlsruhe
Germany

[YC]: Jun-ichi Tsuboi, Mr.
Yamatake Corporation
Shibuyaku Shibuya, 2-12-19
Tohtate International Building
150-8316 Tokyo
Japan

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 and CENELEC shall not be held responsible for identifying any or all such patent rights.

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

IEC 60559	NOTE Harmonized as HD 592 S1:1991 (not modified).
IEC 60870-5-1	NOTE Harmonized as EN 60870-5-1:1993 (not modified).
IEC 61131-2	NOTE Harmonized as EN 61131-2:1994 (not modified).
ISO/IEC 9314-2	NOTE Harmonized as EN 29314-2:1993 (not modified).
ISO/IEC 9646-1	NOTE Harmonized as EN ISO/IEC 9646-1:1996 (not modified).
ISO/IEC 9646-2	NOTE Harmonized as EN ISO/IEC 9646-2:1996 (not modified).

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61158-4:2003 and its corrigendum July 2004 was approved by CENELEC as a European Standard without any modification.

CONTENTS

0	Introduction	27
0.1	General	27
0.2	Nomenclature for references within this standard	27
1	Scope and object	29
1.1	Overview	29
1.2	Specifications	30
1.3	Procedures	32
1.4	Applicability	32
1.5	Conformance	32
2	Normative references	32
3	Terms and definitions	33
3.1	Reference model terms and definitions	33
3.2	Service convention terms and definitions	35
3.3	Common terms and definitions	36
3.4	Type 1: Additional terms and definitions	39
3.5	Type 2: Additional terms and definitions	45
3.6	Type 3: Additional terms and definitions	52
3.7	Type 4: Additional terms and definitions	54
3.8	Type 5: Additional terms and definitions	55
3.9	Type 6: Additional terms and definitions	55
3.10	Type 7: Additional terms and definitions	65
3.11	Type 8: Additional terms and definitions	67
4	Symbols and abbreviations	69
4.1	Common symbols and abbreviations	69
4.2	Type 1: Additional symbols and abbreviations	69
4.3	Type 2: Additional symbols and abbreviations	73
4.4	Type 3: Additional symbols and abbreviations	74
4.5	Type 4: Additional symbols and abbreviations	78
4.6	Type 5: Additional symbols and abbreviations	79
4.7	Type 6: Additional symbols and abbreviations	79
4.8	Type 7: Additional symbols and abbreviations	80
4.9	Type 8: Additional symbols and abbreviations	81
5	DL-protocol elements common to multiple DL-protocol Types	84
5.1	Frame check sequence	84
6	Type 1: Overview of the DL-protocol	88
6.1	Three-level model of the DLL	88
6.2	Service provided by the DLL	91
6.3	Structure and definition of DL-addresses	97
6.4	Service assumed from the PhL	109
6.5	Functions of the DLL	112
6.6	Functional classes	114
6.7	Local parameters, variables, counters, timers and queues	116

7	Type 1: General structure and encoding of PhIDUs and DLPDUs, and related elements of procedure	130
7.1	PhIDU structure and encoding	130
7.2	Common DLPDU structure, encoding and elements of procedure	130
8	Type 1: DLPDU-specific structure, encoding and elements of procedure.....	139
8.1	Establish Connection (EC) DLPDU	141
8.2	Disconnect Connection (DC) DLPDU	143
8.3	Reset Connection (RC) DLPDU	146
8.4	Compel Acknowledgement (CA) DLPDU	147
8.5	Compel Data (CD) DLPDU	154
8.6	Exchange Data (ED) DLPDU	162
8.7	Data (DT) DLPDU.....	170
8.8	Status Response (SR) DLPDU	178
8.9	Compel Time (CT) DLPDU	181
8.10	Time Distribution (TD) DLPDU.....	182
8.11	Round-Trip-Delay Query (RQ) DLPDU	184
8.12	Round-Trip-Delay Reply (RR) DLPDU	186
8.13	Probe Node DL-address (PN) DLPDU.....	188
8.14	Probe Response (PR) DLPDU	191
8.15	Pass Token (PT) DLPDU	192
8.16	Execute Sequence (ES) DLPDU	201
8.17	Return Token (RT) DLPDU	208
8.18	Request Interval (RI) DLPDU.....	209
8.19	Claim LAS (CL) DLPDU	210
8.20	Transfer LAS (TL) DLPDU	212
8.21	Wakeup (WK) DLPDU.....	216
8.22	Idle (IDLE) DLPDU	217
8.23	Spare DLPDUs	218
8.24	Reserved (not to be used) DLPDUs.....	220
9	Type 1: DLPDU-parameter structure and encoding	221
9.1	Structure and encoding of EC-PARAMETERS	221
9.2	Structure and encoding of DC-PARAMETERS	226
9.3	Structure and encoding of RC-PARAMETERS	226
9.4	Structure and encoding of SD-Parameters.....	228
9.5	Structure and encoding of SR-parameters	235
9.6	Structure and encoding of TD-parameters	237
9.7	Structure and encoding of RQ-parameters.....	239
9.8	Structure and encoding of RR-parameters	240
9.9	Structure and encoding of PN-parameters	240
9.10	Structure and encoding of DD-parameters	242
10	Type 1: DL-service elements of procedure	243
10.1	Operation of the DL(SAP)-address, buffer and queue management services	243
10.2	Operation of the connection-mode services	247
10.3	Operation of the connectionless-mode services.....	288
10.4	Operation of the scheduling guidance services	300

11	Type 1: DL-support subprotocol	310
11.1	Scope	310
11.2	Overview of LAS operation	310
11.3	DL-support subprotocol definition	311
11.4	Elements of Procedures for receiving SPDUs	345
12	Type 1: Other DLE elements of procedure.....	347
12.1	DLE initialization	347
12.2	LAS behavior and operation	351
12.3	DL-support operation.....	358
12.4	DL-bridge elements of procedure and bridge sub-protocol.....	363
12.5	DL-management-information	393
12.6	Implementation profiles	398
13	Type 1: PICS proforma.....	404
13.1	Introduction	404
13.2	Scope.....	404
13.3	Normative references	404
13.4	Definitions	404
13.5	Abbreviations	404
13.6	Conformance	405
13.7	Instructions	405
13.8	Identification.....	406
13.9	Implementation profile	407
13.10	Major low-level capabilities.....	411
13.11	Major high-level capabilities	425
14	Type 2: Overview of the DL-protocol	434
14.1	General	434
14.2	Services provided by the DL	436
14.3	Structure and definition of DL-addresses	437
14.4	Services assumed from the PhL	439
14.5	Functional classes.....	441
15	Type 2: General structure and encoding of PhIDUs and DLPDUs and related elements of procedure	442
15.1	Overview	442
15.2	Media access procedure.....	442
15.3	DLPDU structure and encoding	445
15.4	Lpacket components.....	447
15.5	DLPDU procedures.....	449
15.6	Summary of DLL support services and objects	450
16	Type 2: Specific DLPDU structure, encoding and procedures.....	453
16.1	Modeling language	453
16.2	DLS user services	455
16.3	Generic Tag Lpacket	461
16.4	Moderator Lpacket	461
16.5	Time distribution Lpacket.....	463
16.6	UCMM Lpacket.....	465
16.7	Keeper UCMM Lpacket.....	465
16.8	TUI Lpacket.....	466

16.9	Link parameters Lpacket and tMinus Lpacket	467
16.10	I'm alive Lpacket	469
16.11	Ping Lpackets.....	470
16.12	WAMI Lpacket	472
16.13	Debug Lpacket	472
17	Type 2: Objects for station management	474
17.1	General	474
17.2	ControlNet object	475
17.3	Keeper object.....	485
17.4	Scheduling object.....	508
17.5	TCP/IP interface object	517
17.6	Ethernet link object.....	524
18	Type 2: Other DLE elements of procedure	529
18.1	Network Attachment Monitor (NAM).....	529
18.2	Calculating link parameters	536
19	Type 2: Detailed specification of DL components	544
19.1	General	544
19.2	Access Control Machine (ACM)	544
19.3	TxLLC.....	561
19.4	RxLLC.....	565
19.5	Transmit Machine (TxM).....	568
19.6	Receive Machine (RxM).....	571
19.7	Serializer	577
19.8	Deserializer	578
19.9	DLL management	579
20	Type 3: Overview of the DL-protocol	582
20.1	General	582
20.2	Overview of the medium access control and transmission protocol	582
20.3	Transmission modes and DL-entity.....	583
20.4	Service assumed from the PhL	588
20.5	Operational elements	590
20.6	Cycle and system reaction times	605
21	Type 3: General structure and encoding of DLPDUs, and related elements of procedure	609
21.1	DLPDU granularity.....	609
21.2	Length octet (LE, LEr)	610
21.3	Address octet	610
21.4	Control octet (FC).....	613
21.5	DLPDU content error detection	616
21.6	DATA_UNIT	617
21.7	Error control procedures.....	618
22	Type 3: DLPDU-specific structure, encoding and elements of procedure	619
22.1	DLPDUs of fixed length with no data field	619
22.2	DLPDUs of fixed length with data field	621
22.3	DLPDUs with variable data field length	622
22.4	Token DLPDU	624

22.5	ASP DLPDU	625
22.6	SYNCH DLPDU	625
22.7	Time Event (TE) DLPDU	625
22.8	Clock Value (CV) DLPDU	625
22.9	Transmission procedures	626
23	Type 3: Other DLE elements of procedure	629
23.1	DL-entity initialization	629
23.2	States of the media access control of the DL-entity	629
23.3	Clock synchronization protocol	635
24	Type 4: Data Link Protocol Definition	640
24.1	Overview of the DL-protocol	640
24.2	General structure and encoding of PhIDUs and DLPDUs, and related elements of procedure	651
24.3	DLPDU-specific structure, encoding and elements of procedure	657
24.4	DL-service elements of procedure	661
24.5	Route mechanism	664
24.6	Link-access system	668
24.7	Local variables, counters and queues	668
25	Type 5: <placeholder for the Type 5 DL-protocol definition>	671
26	Type 6: Connection-oriented DL-protocol and related matters	673
26.1	Connection mode data transfer using TDMA principles	673
26.2	Bus access and data transmission	673
26.3	Overview of bus synchronization	675
26.4	Connection mode data transfer	678
26.5	DLM-connectionless service	706
26.6	Other real-time services	720
26.7	Bridge architecture and operation	724
26.8	Bus configuration	726
26.9	Conformance	736
27	Type 6: MAC elements of procedure	738
27.1	Procedures related to bus startup and bus operation	738
27.2	Medium access control (MAC)	743
28	Type 7: Overview of the DL-protocol	746
28.1	Overall description of medium allocation	746
28.2	Types of entities	748
28.3	Addressing	751
28.4	Flow control	757
28.5	Graphical representation	759
29	Type 7: General structure and encoding of PhIDUs and DLPDUs and related elements of procedure	760
29.1	DLPDU formats and components	760
29.2	Description of each DLPDU component	760
29.3	PhIDU structure and encoding	762
29.4	Common DLPDU structure, encoding and elements of procedure	763
29.5	Valid DLPDU types	763
29.6	DLL timers	763

30	Type 7: DLPDU-specific structure, encoding and element of procedure.....	771
30.1	General	771
30.2	Buffer read	771
30.3	Buffer write.....	771
30.4	Buffer transfer	771
30.5	Specified explicit request.....	772
30.6	Free explicit request.....	778
30.7	Messaging.....	781
30.8	Acknowledged messaging	786
30.9	Numbering of acknowledged messages	790
30.10	Behavior with mismatched parameters	792
31	Type 7: DL-service elements of procedure, interfaces and conformance	795
31.1	General	795
31.2	Producer/consumer entity	795
31.3	Protocol elements by service.....	798
31.4	Bus arbitrator operation	806
31.5	Bridges.....	813
31.6	Interfaces	820
31.7	Conformance	822
32	Type 8: DL-protocol	825
32.1	Overview	825
32.2	DL-service Interface (DLI)	825
32.3	Peripherals data link (PDL).....	829
32.4	Basic Link Layer (BLL)	864
32.5	Medium Access Control (MAC).....	880
32.6	Peripherals network management for layer 2 (PNM2)	912
32.7	Parameters and monitoring times of the DLL	920
Annex A (informative) – Types 1, 2, 3 (synchronous), 5 (first FCS), 6, 7 and 8: Exemplary FCS implementations.....		926
Annex B (informative) – Type 1: Formal protocol finite state machines.....		928
B.1	Basic reception and transmission FSMs	928
B.2	FSMs for DLCs.....	940
B.3	FSMs for scheduling.....	946
B.4	FSMs for bridges	946
Annex C (informative) – Type 1: DLPDU and DL-addressing short-form summaries		947
C.1	Fields used in short-form summaries	947
C.2	DLPDU short-form summary grouped by function	949
C.3	DLPDU short-form summary in alphabetic order of DLPDU names	951
C.4	DLPDU short-form summary in alphabetic order of DLPDU acronyms.....	952
C.5	DLPDU FC code-point assignment matrix – overview and detail	953
C.6	SD-parameters (status and data-description parameters) of CA, CD, ED and DT DLPDUs.....	956
C.7	EC parameters of EC DLPDUs	959
C.8	Parameters of DC and RC DLPDUs.....	961
C.9	Parameters of TD, RQ and RR DLPDUs	963
C.10	Parameters of PN, PT, ES and RI DLPDUs	965
C.11	Addressing summary extracted from figures and tables of 6.3	

Annex D (informative) – Type 2: Indicators and Switches	971
D.1 Purpose	971
D.2 General indicator requirements	971
D.3 Common indicator requirements	971
D.4 Module status indicator	972
D.5 Network status indicators	972
D.6 Switches	975
Annex E (normative) – Type 3: DL-Protocol state machines	977
E.1 Overall structure	977
E.2 Variation of state machines in different devices	979
E.3 DL Data Resource	979
E.4 FLC / DLM	984
E.5 MAC	1009
E.6 SRU	1038
Annex F (informative) – Type 3: Exemplary token procedure and message transfer periods	1056
F.1 Procedure of token passing	1056
F.2 Examples for token passing procedure	1057
F.3 Examples for message transfer periods – asynchronous transmission	1061
F.4 Examples for message transfer periods – synchronous transmission	1062
Annex G (informative) – Type 7: Object Modeling	1063
G.1 Modeling of the IDENTIFIER object	1063
G.2 Description of the IDENTIFIER object attributes	1064
G.3 Modeling of the QUEUE object	1068
G.4 Description of the QUEUE object attributes	1068
G.5 Modeling of the BUFFER object	1069
G.6 Description of the BUFFER object attributes	1069
Annex H (informative) – Type 7: Topology of multi-segment DL-subnetwork	1070
H.1 Introduction	1070
H.2 Global specification	1070
H.3 Local specification	1071
H.4 Properties	1071
H.5 Methods	1072
Annex I (informative) – Type 7: Management of transmission errors	1075
I.1 Transmission of RP_DAT_XX	1075
I.2 Transmission of a free RP_RQ(1/2)	1075
I.3 Transmission of the specified RP_RQ1	1076
I.4 Transmission of RP_MSG_NOACK	1077
I.5 Transmission of RP_MSG_ACK	1079
Annex J (informative) – Type 8: Implementation possibilities of definite PNM2 functions	1082
J.1 Acquiring the current configuration	1082
J.2 Comparing the acquired and stored configurations prior to a DL-subnetwork error	1085
BIBLIOGRAPHY	1092
INDEX	1094

Figure 1 – Relationship of IEC 61158-4 to other fieldbus layers and to users of the fieldbus Data Link service	27
Figure 2 – Relationships of DLSAPs, DLSAP-addresses and group DL-addresses	38
Figure 3 – Relationships of DLCEPs and DLCEP-addresses to DLSAPs, DLSAP-addresses and group DL-addresses	40
Figure 4 – Basic Structure of a DL-address	98
Figure 5 – Basic Structure of a Sublink Selector	98
Figure 6 – DL-address Alternative Structures	99
Figure 7 – Basic Structure of MAC-addresses	109
Figure 8 – Representation of a DL-address as a MAC-address	109
Figure 9 – Linear relationships of sending and receiving DLCEP sequence-number variables	122
Figure 10 – DL-address alternative structures	133
Figure 11 – SHORT DL-address field – alternative implicit structures	133
Figure 12 – NODE DL-address field – implicit structure	134
Figure 13 – State transition diagram for a DLCEP	247
Figure 14 – Projection of the sending and receiving DLCEP sequence-number variables of Figure 9 onto the cyclic sequence-number parameters of CA, CD, DT, ED and RC DLPDUs, with consequent determination of required actions	264
Figure 15 – State transitions of a DLE	347
Figure 16 – Bridged network topology	364
Figure 17 – Spanning tree representation	365
Figure 18 – DLSDU transit delay, DLPDU lifetime and bridge forwarding delay	369
Figure 19 – Forwarding and delivering a received DLPDU	373
Figure 20 – Forwarding a locally-originated DLPDU	374
Figure 21 – Republishing a DLSDU received from another link	375
Figure 22 – Bridge architecture	376
Figure 23 – Replacement for [IL] Fig 3-2 Bridge ports	385
Figure 24 – Replacement for [IL] Fig 3-3 Bridge architecture	386
Figure 25 – Data Link Layer internal architecture	435
Figure 26 – Basic Structure of a MAC ID address	437
Figure 27 – Basic Structure of a Generic tag address	437
Figure 28 – Basic Structure of a Fixed tag address	438
Figure 29 – M_symbols and Manchester encoding at 5 MHz (informative)	439
Figure 30 – NUT structure	443
Figure 31 – Media access during scheduled time	443
Figure 32 – Media access during unscheduled time	444
Figure 33 – DLPDU format	445
Figure 34 – Aborting a DLPDU during transmission	446
Figure 35 – Lpacket format	447
Figure 36 – Generic tag Lpacket format	448
Figure 37 – Fixed tag Lpacket format	448
Figure 38 – goodness parameter of TimeDist_Lpacket	463
Figure 39 – Example I'm alive processing algorithm	470
Figure 40 – Keeper CRC algorithm	491
Figure 41 – Keeper object power-up state diagram	503

Figure 42 – Keeper object operating state diagram	504
Figure 43 – Synchronized network change processing	507
Figure 44 – State transition diagram for TCP/IP interface object	524
Figure 45 – NAM state machine	530
Figure 46 – Logical Token Passing ring	585
Figure 47 – PhL data service for asynchronous transmission	589
Figure 48 – Idle time T_{ID1}	592
Figure 49 – Idle time T_{ID2} (SDN, CS)	592
Figure 50 – Idle time T_{ID2} (MSRD)	593
Figure 51 – Slot time T_{SL1}	593
Figure 52 – Slot time T_{SL2}	594
Figure 53 – Slot time T_{SL1}	599
Figure 54 – Slot time T_{SL2}	599
Figure 55 – Token transfer period	605
Figure 56 – Message transfer period.....	606
Figure 57 – UART character	609
Figure 58 – Octet structure	610
Figure 59 – Length octet coding.....	610
Figure 60 – Address octet coding.....	610
Figure 61 – DAE/SAE octet in the DLPDU.....	611
Figure 62 – Address extension octet.....	612
Figure 63 – FC octet coding for send/request DLPDUs	613
Figure 64 – FC octet coding for acknowledgement or response DLPDUs	613
Figure 65 – FCS octet coding.....	616
Figure 66 – Data field	617
Figure 67 – Ident user data.....	617
Figure 68 – DLPDUs of fixed length with no data field.....	619
Figure 69 – DLPDUs of fixed length with no data field.....	620
Figure 70 – DLPDUs of fixed length with data field	621
Figure 71 – DLPDUs of fixed length with data field	622
Figure 72 – DLPDUs with variable data field length.....	623
Figure 73 – DLPDUs with variable data field length.....	624
Figure 74 – Token DLPDU	624
Figure 75 – Token DLPDU	625
Figure 76 – Send/request DLPDU of fixed length with no data	626
Figure 77 – Token DLPDU and send/request DLPDU of fixed length with data.....	626
Figure 78 – Send/request DLPDU with variable data field length.....	627
Figure 79 – Send/request DLPDU of fixed length with no data	627
Figure 80 – Token DLPDU and send/request DLPDU of fixed length with data.....	628
Figure 81 – Send/request DLPDU with variable data field length.....	628
Figure 82 – DL-state-diagram	630
Figure 83 – Overview of clock synchronization.....	636
Figure 84 – Time master state machine	637
Figure 85 – Time receiver state machine	638
Figure 86 – Clock synchronization	638

Figure 87 – Relationship of PhE, DLE and DLS-user.....	640
Figure 88 – DLE state diagram for confirmed and unconfirmed, unacknowledged DLPDUs .	642
Figure 89 – DLE state diagram for confirmed acknowledged DLPDUs.....	643
Figure 90 – DLE state diagram for unconfirmed acknowledged DLPDUs.....	644
Figure 91 – Full duplex DLE receive state diagram	645
Figure 92 – Full duplex DLE transmit state diagram	645
Figure 93 – Link access example	648
Figure 94 – Simple P-NET-route format	654
Figure 95 – Extended P-NET-route format	654
Figure 96 – Complex P-NET-route format	655
Figure 97 – Immediate P-NET-route format.....	655
Figure 98 – Control-status format.....	656
Figure 99 – Data-field-format	657
Figure 100 – Source / destination designator	665
Figure 101 – Simple P-NET-route generation.....	666
Figure 102 – Extended P-NET-route generation.....	666
Figure 103 – Complex P-NET-route generation.....	667
Figure 104 – Simple DL-route generation.....	667
Figure 105 – Extended DL-route generation.....	667
Figure 106 – Complex DL-route generation.....	668
Figure 107 – Connection mode operation using TDMA.....	673
Figure 108 – Fundamental access concepts	674
Figure 109 – EXAMPLE: Architecture of a synchronizer showing one upper port bridge-DLE synchronizing multiple lower port bridge-DLEs	676
Figure 110 – EXAMPLE: Architecture of a forwarding bridge showing one upper port bridge-DLE synchronizing exactly one lower port bridge-DLE	676
Figure 111 – EXAMPLE: Lower-port bridge DLE	677
Figure 112 – EXAMPLE: Bridged network using forwarding bridges	678
Figure 113 – Operation of the SCAN channel-class and its associated primitives.....	679
Figure 114 – Operation of the ExSCAN channel-class and its associated primitives.....	681
Figure 115 – Operation of the GPA channel class and its associated primitives	683
Figure 116 – Data Transfer on the GPC channel-class and its associated primitives	687
Figure 117 – Transfer DLPDU composition on a UNITARY channel.....	691
Figure 118 – Initial-grain DLPDU composition.....	693
Figure 119 – Initial-grain header composition.....	694
Figure 120 – Middle-grain DLPDU composition	695
Figure 121 – Middle-grain header composition.....	696
Figure 122 – Final-grain DLPDU composition.....	696
Figure 123 – Final-grain header composition	697
Figure 124 – DL-status-header and DL-status DLPDU	698
Figure 125 – DLPDU transmission format for 1 WAY or 2 WAY transmission method.....	704
Figure 126 – EXAMPLE: Three level real network with two superimposed virtual networks .	705
Figure 127 – Operation of DLM-connectionless service and its primitives	706
Figure 128 – DLM-connectionless DLPDU composition and encoding	708
Figure 129 – Node DLMSDU composition and encoding	712
Figure 130 – Node-check DLMSDU composition and encoding	715

Figure 131 – Configuration-status parameter composition.....	716
Figure 132 – DLM-connectionless DL-addresses, symbols and their relationships	717
Figure 133 – General form and encoding of DLM-connectionless DL-addresses	717
Figure 134 – Architecture of a forwarding bridge.....	724
Figure 135 – EXAMPLE: Forwarding through a bridge by slot matching	724
Figure 136 – Channel-mode composition and encoding	730
Figure 137 – Half-forwarding-port mode composition and encoding	732
Figure 138 – Configuration-status field composition	733
Figure 139 – Bus-config field composition and encoding	739
Figure 140 – General description of medium allocation	747
Figure 141 – Internal structure of a producer/consumer entity.....	748
Figure 142 – Associated buffers and queues	750
Figure 143 – Internal structure of a bus arbitrator	751
Figure 144 – Polling BA Table	751
Figure 145 – Addressing scheme	752
Figure 146 – Address partitioning	754
Figure 147 – Structure of an individual physical address.....	755
Figure 148 – Structure of an individual logical address	755
Figure 149 – Structure of restricted physical group address.....	755
Figure 150 – Structure of restricted logical group address	756
Figure 151 – Structure of a generalized group address	756
Figure 152 – Summary of address structure.....	757
Figure 153 – Example of an evaluation net	759
Figure 154 – Basic DLPDU structure.....	760
Figure 155 – DLPDU transmission / reception order.....	760
Figure 156 – Identifier DLPDU	764
Figure 157 – Variable response DLPDU.....	764
Figure 158 – Request response DLPDU.....	764
Figure 159 – Message response DLPDU.....	765
Figure 160 – Acknowledgement response DLPDU	765
Figure 161 – End of message transaction response DLPDU	765
Figure 162 – Buffer reading service interactions	771
Figure 163 – Buffer writing service interactions.....	771
Figure 164 – Buffer transfer service interactions	772
Figure 165 – Buffer transfer DLPDU sequence.....	772
Figure 166 – Interactions within the <u>specified explicit request</u> for buffer transfer service in the <u>aperiodic window</u>	774
Figure 167 – Interactions within the <u>specified explicit request</u> for buffer transfer service in the <u>periodic window</u>	775
Figure 168 – DLPDU sequence for an explicit request for a transfer	776
Figure 169 – Evaluation network for a buffer transfer specified explicit request with (RQ_INHIBITED = False).....	777
Figure 170 – Evaluation network for a buffer transfer specified explicit request with (RQ_INHIBITED = True)	777
Figure 171 – Diagram of interactions within the <u>free explicit request</u> for buffer transfer service.....	779
Figure 172 – Evaluation network for a free explicit request	780

Figure 173 – Diagram of interactions within the unacknowledged message transfer request service for an aperiodic transfer	783
Figure 174 – Diagram of interactions within the unacknowledged message transfer request service for a cyclical transfer	784
Figure 175 – DLPDU sequence for an aperiodic message transfer	785
Figure 176 – DLPDU sequence for a cyclical message transfer	786
Figure 177 – Diagram of interactions within the acknowledged message transfer request service for an aperiodic transfer	787
Figure 178 – Diagram of interactions within the acknowledged message transfer request service for a cyclical transfer	788
Figure 179 – DLPDU sequence for an aperiodic message transfer	789
Figure 180 – DLPDU sequence for a cyclical message transfer	790
Figure 181 – Evaluation network for message aperiodic transfer	793
Figure 182 – Evaluation network for message cyclic transfer	794
Figure 183 – Simplified states machine for a producer/consumer entity	795
Figure 184 – Active bus arbitrator's simplified state machine	811
Figure 185 – Typical bridge usage	813
Figure 186 – Architectural placement of bridges in OSI Basic Reference Model (ISO/IEC 7498)	813
Figure 187 – Representation of an extended link communication	814
Figure 188 – Evaluation network for reception of an RP_MSG_ACK DLPDU	819
Figure 189 – Evaluation network for reception of an RP_MSG_NOACK DLPDU	820
Figure 190 – Data Link Layer Entity	825
Figure 191 – Location of the DLI in the DLL	825
Figure 192 – State transition diagram of DLI	827
Figure 193 – Location of the PDL in the DLL	829
Figure 194 – PDL connection between slave and master	830
Figure 195 – Interface between PDL-user (DLI) and PDL in the layer model	830
Figure 196 – Overview of the PDL services	831
Figure 197 – PDL_Data_Ack service between master and only one slave	832
Figure 198 – Parallel processing of PDL_Data_Ack services	833
Figure 199 – PSM and GSM service for buffer access	833
Figure 200 – Buffer_Received service to indicate successful data transfer	833
Figure 201 – Data flow between PDL-user, PDL and BLL of a PDL_Data_Ack service	836
Figure 202 – Interface between PDL and PNM2 in the layer model	837
Figure 203 – Reset, Set Value and Get Value PDL services	838
Figure 204 – Event PDL service	838
Figure 205 – Transmit and receive FCBs on the master and slave sides	842
Figure 206 – Data transmission master → slave with SWA Message	842
Figure 207 – Time sequence of the data transmission master → slave with SWA Message	843
Figure 208 – Data transmission slave → master with SWA/RWA Message	843
Figure 209 – Time sequence of the data transmission slave → master with SWA/RWA Message	844
Figure 210 – Allocation of actions of the PDL protocol machines and data cycles	845
Figure 211 – Message transmission: master → slave	845
Figure 212 – Message transmission: slave → master	845

Figure 213 – Code octet of a PDL PDU	846
Figure 214 – Structure of a message with a size of one word	847
Figure 215 – Structure of a SPA Message	848
Figure 216 – Structure of a SVA Message	848
Figure 217 – Structure of a FCB_SET Message	848
Figure 218 – Structure of a RWA Message	849
Figure 219 – Structure of a SWA Message	849
Figure 220 – Structure of a confirmation for SPA or SVA Messages	849
Figure 221 – Structure of a FCB_SET as confirmation	849
Figure 222 – Structure of the data octet for FCB_SET as requests and confirmations	850
Figure 223 – Structure of a message with a size of more than one word	850
Figure 224 – PDL base protocol machine	852
Figure 225 – Locations of the PDL and the PDL protocol machines in the master and slaves	854
Figure 226 – PDL protocol machine	855
Figure 227 – TRANSMIT protocol machine	858
Figure 228 – RECEIVE protocol machine	861
Figure 229 – Location of the BLL in the DLL	864
Figure 230 – Interface between PDL and BLL in the layer model	865
Figure 231 – BLL_Data service	866
Figure 232 – Interface between PNM2 and BLL in the layer model	868
Figure 233 – Reset, Set Value and Get Value BLL services	869
Figure 234 – Event BLL service	870
Figure 235 – BLL operating protocol machine of the master	874
Figure 236 – BLL-BAC protocol machine	876
Figure 237 – BLL operating protocol machine of the slave	879
Figure 238 – Location of the MAC in the DLL	880
Figure 239 – Model details of layers 1 and 2	880
Figure 240 – DLPDU cycle of a data sequence without errors	881
Figure 241 – DLPDU cycle of a data sequence with errors	881
Figure 242 – Data sequence DLPDU transmitted by the master	882
Figure 243 – Data sequence DLPDU received by the master	882
Figure 244 – Check sequence DLPDU	882
Figure 245 – Loopback word (LBW)	883
Figure 246 – Checksum status generated by the master	883
Figure 247 – Checksum status received by the master	883
Figure 248 – MAC protocol machine of a master: transmission of a message	885
Figure 249 – MAC protocol machine of a master: receipt of a message	888
Figure 250 – MAC sublayer of a master: data sequence identification	892
Figure 251 – Data sequence DLPDU received by a slave	895
Figure 252 – Data sequence DLPDU transmitted by a slave	895
Figure 253 – Checksum status received by the slave	895
Figure 254 – Checksum status generated by the slave	896
Figure 255 – State transitions of the MAC sublayer of a slave: data sequence	897
Figure 256 – State transitions of the MAC sublayer of a slave: check sequence	898
Figure 257 – Interface between MAC-user and MAC in the layer model	899

Figure 258 – Interactions at the MAC-user interface (master)	904
Figure 259 – Interactions at the MAC-user interface (slave).....	905
Figure 260 – Interface between MAC and PNM2 in the layer model	908
Figure 261 – Reset, Set Value and Get Value MAC services.....	910
Figure 262 – Event MAC service	910
Figure 263 – Location of the PNM2 in the DLL	912
Figure 264 – Interface between PNM2-user and PNM2 in the layer model	913
Figure 265 – Reset, Set Value, Get Value and Get Active Configuration services	915
Figure 266 – Event PNM2 service	915
Figure 267 – Set Active Configuration, Get Current Configuration service.....	915
Figure 268 – The active_configuration parameter	919
Figure 269 – Device code structure.....	922
Figure 270 – Relations between data width, process data channel and parameter channel.....	924
Figure 271 – Structure of the control code	925
Figure A.1 – Example of FCS generation for Types 1, 3 (synchronous), 5 (first FCS), 6 and 7	926
Figure A.2 – Example of FCS syndrome checking on reception for Types 1, 3 (synchronous), 5 (first FCS), 6 and 7	926
Figure C.1 – Gross structure of FC code points	953
Figure C.2 [Figure 4] – Basic structure of a DL-address	967
Figure C.3 [Figure 5] – Basic structure of a sublink selector.....	967
Figure C.4 [Figure 6] – DL-address alternative structures	967
Figure C.5 [Figure 7] – Basic structure of MAC-addresses	967
Figure C.6 [Figure 8] – Representation of a DL-address as a MAC-address	967
Figure D.1 – Non redundant network status indicator labeling	975
Figure D.2 – Redundant network status indicator labeling	975
Figure E.1 – Structuring of the protocol machines	978
Figure E.2 – Structure of the SRU Machine.....	1039
Figure F.1 – Derivation of the token holding time (T_{TH})	1057
Figure F.2 – No usage of token holding time (T_{TH}).....	1058
Figure F.3 – Usage of token holding time (T_{TH}) for message transfer (equivalence between T_{TH} of each Master station).....	1059
Figure F.4 – Usage of token holding time (T_{TH}) in different working load situations.....	1060
Figure I.1 – Evaluation DL-subnetwork for transmission of RP_DAT_XX	1075
Figure I.2 – Evaluation DL-subnetwork for transmission of a free RP_RQ(1/2)	1076
Figure I.3 – Evaluation DL-subnetwork for transmission of the specified RP_RQ1.....	1077
Figure I.4 – Evaluation DL-subnetwork for transmission of RP_MSG_NOACK, first behavior.....	1078
Figure I.5 – Evaluation DL-subnetwork for transmission of RP_MSG_NOACK, second behavior	1079
Figure I.6 – Evaluation DL-subnetwork for transmission of RP_MSG_ACK, first behavior.....	1080
Figure I.7 – Evaluation DL-subnetwork for transmission of RP_MSG_ACK, second behavior	1081
Figure J.1 – DL-subnetwork configuration in the form of a tree structure	1082
Figure J.2 – State machine for the acquisition of the current configuration	1084

Figure J.3 – State machine for comparing two configurations	1088
Figure J.4 – State machine for comparing one line of two configuration matrices	1090

Table 1 – FCS length, polynomials and constants by protocol Type	85
Table 2 – Link node selector addressing	101
Table 3 – Link-local node selector addressing.....	103
Table 4 – Link-local node designators.....	104
Table 5 – Node-local selector addressing	106
Table 6 – Predefined flat non-local DL-addresses	107
Table 7 – Predefined flat link-local DL-addresses	108
Table 8 – Predefined node-local DL-addresses	108
Table 9 – Correlation of DLPDUs with functional classes	114
Table 10 – Summary structure of DLPDUs	140
Table 11 – DLPDU restrictions based on dominant token.....	141
Table 12 – Structure of EC DLPDUs	141
Table 13 – Structure of DC DLPDUs	144
Table 14 – Structure of RC DLPDUs	146
Table 15 – Structure of CA DLPDUs	148
Table 16 – Structure of CD DLPDUs	154
Table 17 – Structure of ED DLPDUs	162
Table 18 – Structure of DT DLPDUs	171
Table 19 – Structure of SR DLPDUs	178
Table 20 – Structure of CT DLPDUs	181
Table 21 – Structure of TD DLPDUs	182
Table 22 – Structure of RQ DLPDUs.....	184
Table 23 – Structure of RR DLPDUs	187
Table 24 – Structure of PN DLPDUs	188
Table 25 – Structure of PR DLPDUs	191
Table 26 – Structure of PT DLPDUs.....	193
Table 27 – Structure of ES DLPDUs	202
Table 28 – Structure of RT DLPDUs	208
Table 29 – Structure of RI DLPDUs.....	209
Table 30 – Structure of CL DLPDUs.....	211
Table 31 – Structure of TL DLPDUs	212
Table 32 – Structure of WK DLPDUs.....	216
Table 33 – Structure of IDLE DLPDUs.....	217
Table 34 – Assumed structure of undefined (spare) DLPDUs	219
Table 35 – Assumed structure of RESERVED (NOT TO BE USED) DLPDUs	220
Table 36 – Structure of an EC DLPDU's parameters	221
Table 37 – EC-parameters: 1st octet.....	221
Table 38 – EC-parameters: 2nd octet.....	222
Table 39 – EC-parameters: 3rd and 4th octets	222
Table 40 – EC-parameters: 5th and 6th octets	223
Table 41 – EC-parameters: 7th octet	223
Table 42 – EC-parameters: 8th octet	223
Table 43 – EC-parameters: 9th and 10th octets	223

Table 44 – EC-parameters: 11th octet.....	224
Table 45 – EC-parameters: 12th octet.....	225
Table 46 – EC-parameters: 13th and 14th octets	225
Table 47 – DC-parameters and RC-parameters: 1st octet	226
Table 48 – DC-parameters and RC-parameters: 2nd octet	226
Table 49 – Disconnect reasons	227
Table 50 – Reset reasons	228
Table 51 – RC-parameters: 3rd octet	228
Table 52 – RC-parameters: 4th octet	228
Table 53 – Structure of connectionless-mode CA, CD, DT and ED DLPDUs.....	229
Table 54 – Short format SD-parameters for connectionless transaction initiators	230
Table 55 – Short format SD-parameters for connectionless responders	230
Table 56 – Reply status for unitdata-acknowledgment and exchange-unitdata-reply DT DLPDUs.....	231
Table 57 – Structure of connection-oriented CA, CD, DT and ED DLPDUs.....	233
Table 58 – Short format SD-parameters for DLCEP state.....	234
Table 59 – Long format SD-parameters for DLCEP state: 1st octet	234
Table 60 – Long format SD-parameters for DLCEP state: 2nd octet.....	234
Table 61 – Long format SD-parameters for DLCEP state: 3rd octet.....	235
Table 62 – Reply status for SR DLPDUs	236
Table 63 – Short format SR-parameters.....	236
Table 64 – Structure of TD-parameters	237
Table 65 – Structure and encoding of the DL-time-quality measures	237
Table 66 – Approximate numeric significance of the bits of seven-octet DL-time	238
Table 67 – Approximate numeric significance of the bits of three-octet short time	239
Table 68 – Structure of RQ-parameters	239
Table 69 – Structure of RR-parameters.....	240
Table 70 – Structure and encoding of the RR-time-quality measures	240
Table 71 – Structure of PN-parameters.....	241
Table 72 – PN-parameters: 1st octet.....	241
Table 73 – PN-parameters: 2nd octet.....	241
Table 74 – PN-parameters: 3rd and 4th octets	242
Table 75 – PN-parameters: 5th octet	242
Table 76 – PN-parameters: 6th octet	242
Table 77 – Structure of DD-parameters.....	242
Table 78 – Components of returned DL-time.....	300
Table 79 – Time synchronization computation.....	302
Table 80 – SPDU 1st octet: SPDU class, and protocol version or subclass	311
Table 81 – Probe-response SPDU	312
Table 82 – DL-protocol versions supported.....	312
Table 83 – PR-SPDU: 3rd and 4th octets	313
Table 84 – Node-activation SPDU.....	314
Table 85 – Node-activation SPDU: 4th octet	314
Table 86 – LAS-data-base-status SPDU	315
Table 87 – LAS-data-base-status SPDU: 2nd octet	315
Table 88 – Live-list- change SPDU	316

Table 89 – DLE-status structure.....	316
Table 90 – Live-list-detail SPDU	317
Table 91 – DL-conformance-reply SPDU.....	318
Table 92 – DL-protocol versions supported	318
Table 93 – DL-conformance encoding (portion 1).....	319
Table 94 – DL-conformance encoding (portion 2).....	319
Table 95 – DL-conformance encoding (portion 3).....	319
Table 96 – DL-conformance encoding (portion 4).....	320
Table 97 – Link-basic-parameters-reply SPDU	320
Table 98 – Link-master-parameters-reply SPDU	321
Table 99 – Token-hold-time-request SPDU	322
Table 100 – Token-hold-time-array SPDU	323
Table 101 – Sequence element header encoding	325
Table 102 – SHORT DL-address and duration sequence element	325
Table 103 – LONG DL-address and duration sequence element	326
Table 104 – Wakeup request sequence element	326
Table 105 – Schedule-request SPDU	327
Table 106 – Sequence type, schedule type and priority encoding	327
Table 107 – Scheduling-completed SPDU.....	329
Table 108 – Status and reason codes	329
Table 109 – Cancel-schedule SPDU	330
Table 110 – Schedule-cancelled SPDU.....	330
Table 111 – Link-schedule	331
Table 112 – Schedule-summary SPDU	332
Table 113 – Subschedule-SPDU reference	333
Table 114 – Subschedule SPDU	333
Table 115 – Sequence Sub-SPDU	334
Table 116 – Element-description.....	335
Table 117 – Schedule-summary-request SPDU.....	336
Table 118 – Subschedule-request SPDU	336
Table 119 – Parameter-list element-header encoding	337
Table 120 – Begin/end-of-list element.....	337
Table 121 – Continuation-of-list element.....	338
Table 122 – SHORT DL-address list element	338
Table 123 – LONG DL-address element	339
Table 124 – DLSAP-address-characteristics element.....	339
Table 125 – DLCEP-characteristics element	340
Table 126 – Address-query SPDU	340
Table 127 – Address-report SPDU	341
Table 128 – Address-list-query SPDU	342
Table 129 – DL-address selection criteria	343
Table 130 – Address-list-reply SPDU	344
Table 131 – Topology change notification BPDU format.....	393
Table 132 – Configuration BPDU format	393
Table 133 – Maximum permitted phase-tracking error in a DLE's sense of DL-time at the minimum requireable Time Distribution period	402

Table 134 – Data Link Layer components	434
Table 135 – MAC ID addresses allocation.....	437
Table 136 – Fixed tag service definitions	438
Table 137 – Data encoding rules	439
Table 138 – M Data symbols.....	440
Table 139 – Truth table for ph_status_indication.....	441
Table 140 – DLL support services and objects	451
Table 141 – Elementary data types	454
Table 142 – DLL events	459
Table 143 – Time distribution priority	464
Table 144 – Format of the TUI Lpacket.....	467
Table 145 – ControlNet object class attributes	475
Table 146 – ControlNet object instance attributes	475
Table 147 – TUI status flag bits	479
Table 148 – Channel state bits	481
Table 149 – ControlNet object common services.....	482
Table 150 – ControlNet object class specific services	483
Table 151 – Keeper Object revision history.....	485
Table 152 – Keeper object class attributes.....	485
Table 153 – Keeper object instance attributes.....	486
Table 154 – Keeper operating state definitions	489
Table 155 – Port status flag bit definitions	489
Table 156 – TUI status flag bits	490
Table 157 – Keeper attributes.....	492
Table 158 – Memory requirements (in octets) for the Keeper attributes.....	493
Table 159 – Keeper object common services	493
Table 160 – Keeper class specific services.....	494
Table 161 – Service error codes	495
Table 162 – Wire order format of the TUI Lpacket.....	499
Table 163 – Service error codes	500
Table 164 – Keeper object operating states	501
Table 165 – Keeper object state event matrix	505
Table 166 – Scheduling object class attributes	508
Table 167 – Scheduling object instance attributes	509
Table 168 – Services at class level and instance level.....	509
Table 169 – Status error descriptions for Create.....	510
Table 170 – Status error descriptions for Delete and Kick_Timer	511
Table 171 – Status error descriptions for Read	512
Table 172 – Status error descriptions for Conditional_Write.....	513
Table 173 – Status error descriptions for Forced_Write.....	514
Table 174 – Status error descriptions for Change_Start.....	514
Table 175 – Status error descriptions for Break_Connections	515
Table 176 – Status error descriptions for Change_Complete.....	516
Table 177 – Status error descriptions for Restart_Connections	516
Table 178 – TCP/IP interface object class attributes	518
Table 179 – TCP/IP interface object instance attributes	

Table 180 – Status values.....	520
Table 181 – Configuration capability bits.....	520
Table 182 – Configuration control bits.....	520
Table 183 – Example path	521
Table 184 – Interface configuration components	522
Table 185 – TCP/IP interface object common services.....	523
Table 186 – Get_Attribute_All reply format.....	523
Table 187 – Ethernet link object class attributes	525
Table 188 – Ethernet link object instance attributes	525
Table 189 – Interface flags bits	527
Table 190 – Ethernet link object common services.....	528
Table 191 – Ethernet link object class specific services	528
Table 192 – NAM states.....	529
Table 193 – Default link parameters.....	530
Table 194 – PhL timing characteristics.....	537
Table 195 – Characteristic features of the fieldbus Data Link protocol	582
Table 196 – Transmission function code No.....	614
Table 197 – FCB, FCV in responder	616
Table 198 – Operating parameters.....	629
Table 199 – Summary structure of DLPDUs	657
Table 200 – Structure of Confirmed DLPDUs	658
Table 201 – Structure of Unconfirmed DLPDUs	659
Table 202 – Structure of Acknowledge DLPDU	660
Table 203 – Structure of Immediate-reply DLPDU	660
Table 204 – Primitives and parameters used on SCAN channels	679
Table 205 – Primitives and parameters used on ExSCAN channels	681
Table 206 – Correspondence of max-DLSDU-size and max-data-length for GPA, GPC and ExSCAN channels	682
Table 207 – Primitives and parameters used on GPA channels.....	683
Table 208 – Primitives and parameters used for data transfer on GPC channels.....	687
Table 209 – Primitives and parameters used to disconnect GPC channels.....	688
Table 210 – Primitives and parameters used for DLM-connectionless service.....	707
Table 211 – Predefined functional and group addresses	718
Table 212 – Predefined trigger assignments	719
Table 213 – Format of link-addresses	720
Table 214 – DL-TIME-OFFSET parameter composition.....	721
Table 215 – Time-Offset primitive and parameters	721
Table 216 – DL-time classes.....	721
Table 217 – Time stamp primitives and parameters	722
Table 218 – Time stamp parameter composition	722
Table 219 – DL-Event-time primitive and parameters	723
Table 220 – Channel DLMSDU composition and encoding.....	729
Table 221 – Trigger DLMSDU composition and encoding.....	731
Table 222 – Half-forwarding-port DLMSDU composition and encoding.....	732
Table 223 – Channel check DLMSDU composition and encoding.....	733
Table 224 – Trigger-check DLMSDU composition and encoding.....	734

Table 225 – Half-forwarding-port DLMSDU composition and encoding	735
Table 226 – Bus-PDU composition and encoding	738
Table 227 – Individual and group address encoding	754
Table 228 – DLPDU control-field coding	761
Table 229 – Correspondence between name and coding of 8 bits in the control field	762
Table 230 – DL-Timers	768
Table 231 – Bus arbitrator state transition table	812
Table 232 – Bridge object description	815
Table 233 – Channel object description	816
Table 234 – Segment directory object description	817
Table 235 – Network directory object description	817
Table 236 – Service primitives by type	821
Table 237 – Conformance classes	824
Table 238 – Primitives issued by DLS-/DLMS-user to DLI	826
Table 239 – Primitives issued by DLI to DLS-/DLMS-user	826
Table 240 – DLI state table – sender transactions	827
Table 241 – DLI state table – receiver transactions	828
Table 242 – Function GetOffset	829
Table 243 – Function GetLength	829
Table 244 – Function GetRemAdd	829
Table 245 – Function GetDlsUserId	829
Table 246 – PDL_Data_Ack	834
Table 247 – PDL_Data_Ack L_status values	834
Table 248 – PSM	834
Table 249 – GSM	835
Table 250 – PDL_Reset	839
Table 251 – PDL_Set_Value	839
Table 252 – PDL variables	839
Table 253 – PDL_Get_Value	840
Table 254 – PDL_Event	840
Table 255 – Events	840
Table 256 – Encoding of the L_status	846
Table 257 – FCT code (PDL PDU-Types)	847
Table 258 – State transitions of the PDL base protocol machine	852
Table 259 – Counters of the PDL protocol machines	854
Table 260 – Meaning of the "connection" flag	855
Table 261 – State transitions of the PDL protocol machine	856
Table 262 – State transitions of the TRANSMIT protocol machine	859
Table 263 – State transitions of the RECEIVE protocol machine	862
Table 264 – BLL_Data	867
Table 265 – BLL_Data	870
Table 266 – BLL_Reset	871
Table 267 – BLL_Set_Value	871
Table 268 – BLL variables	871
Table 269 – BLL_Get_Value	872
Table 270 – BLL_Event	872

Table 271 – BLL_Event.....	872
Table 272 – State transitions of the BLL operating protocol machine of the master	875
Table 273 – State transitions of the BLL-BAC protocol machine.....	877
Table 274 – State transitions of the BLL operating protocol machine of the slave	879
Table 275 – MAC_Reset	910
Table 276 – MAC_Set_Value	910
Table 277 – MAC variables	911
Table 278 – MAC_Get_Value.....	911
Table 279 – MAC_Event	911
Table 280 – MAC_Event	912
Table 281 – PNM2_Reset	916
Table 282 – M_status values of the PNM2_Reset	916
Table 283 – PNM2_Set_Value	916
Table 284 – M_status values of the PNM2_Set_Value	917
Table 285 – PNM2_Get_Value.....	917
Table 286 – M_status values of the PNM2_Get_Value	917
Table 287 – PNM2_Event	918
Table 288 – MAC Events	918
Table 289 – PNM2_Get_Current_Configuration	918
Table 290 – PNM2_Get_Active_Configuration	919
Table 291 – PNM2_Set_Active_Configuration.....	920
Table 292 – Data direction.....	922
Table 293 – Number of the occupied octets in the parameter channel.....	923
Table 294 – Device class	923
Table 295 – Control data	923
Table 296 – Data width	924
Table 297 – Medium control.....	925
Table C.1 – Generic assignment of FC code points.....	954
Table C.2 – Individual assignment of FC code points	955
Table C.3 – Reply status for SR DLPDUs	958
Table C.4 – Reply status for unitdata-acknowledgment and exchange-unitdata-reply DT DLPDUs.....	959
Table C.5 – Approximate numeric significance of the bits of seven-octet DL-time	964
Table C.6 – Approximate numeric significance of the bits of N(NT), A...A, and three-octet C(NT)	964
Table C.7 [Table 2] – Link node selector addressing	968
Table C.8 [Table 3] – Link-local node selector addressing	968
Table C.9 [Table 6] – Predefined flat non-local DL-addresses	969
Table C.10 [Table 7] – Predefined flat link-local DL-addresses	969
Table C.11 [Table 4] – Link-local node designators.....	970
Table C.12 [Table 5] – Node-local selector addressing	970
Table C.13 [Table 8]– Predefined node-local DL-addresses	970
Table D.1 – Network status indicators.....	973
Table E.1 – Assignment of state machines.....	979
Table E.2 – Data resource	980
Table E.3 – Primitives issued by DL-User to FLC	984

Table E.4 – Primitives issued by FLC to DL-User	985
Table E.5 – Primitives issued by DL-User to DLM	986
Table E.6 – Primitives issued by DLM to DL-User	987
Table E.7 – Parameters used with primitives exchanged between DL-User and FLC	988
Table E.8 – Parameters used with primitives exchanged between DL-User and DLM	988
Table E.9 – FLC / DLM state table	990
Table E.10 – FLC / DLM function table	1003
Table E.11 – Primitives issued by DLM to MAC	1010
Table E.12 – Primitives issued by MAC to DLM	1010
Table E.13 – Parameters used with primitives exchanged between DLM and MAC	1010
Table E.14 – Local MAC variables	1011
Table E.15 – MAC state table	1012
Table E.16 – MAC function table	1034
Table E.17 – Primitives issued by DLM to SRC	1041
Table E.18 – Primitives issued by SRC to DLM	1041
Table E.19 – Primitives issued by MAC to SRC	1041
Table E.20 – Primitives issued by SRC to MAC	1042
Table E.21 – Parameters used with primitives exchanged between MAC and SRC	1042
Table E.22 – FC structure	1042
Table E.23 – Local variables of SRC	1043
Table E.24 – SRC state table	1043
Table E.25 – SRC functions	1055
Table J.1 – DL-subnetwork configuration in the form of a matrix	1083
Table J.2 – Acquire_Configuration	1083
Table J.3 – State transitions of the state machine for the acquisition of the current configuration	1085
Table J.4 – Check_Configuration	1086
Table J.5 – Compare_Slave	1087
Table J.6 – State transitions of the state machine for comparing two configurations	1089
Table J.7 – State transitions of the state machine for comparing one line of two configuration matrixes	1091

0 Introduction

0.1 General

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, which is based in part on the Basic Reference Model for Open Systems Interconnection. Both Reference Models subdivide the area of standardization for interconnection into a series of layers of specification, each of manageable size.

The Data Link Protocol provides the Data Link Service by making use of the services available from the Physical Layer. The relationship between the International Standards for Fieldbus Data Link Service, Fieldbus Data Link Protocol, Fieldbus Physical Service and Systems Management is illustrated in Figure 1.

NOTE Systems Management, as used in this standard, is a local mechanism for managing the layer protocols.

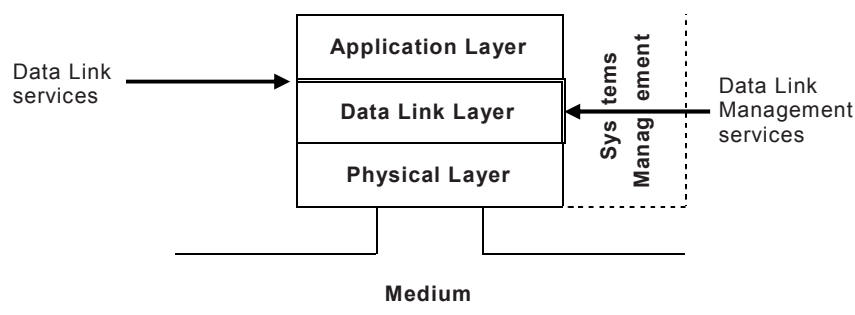


Figure 1 – Relationship of IEC 61158-4 to other fieldbus layers and to users of the fieldbus Data Link service

The primary aim of this standard is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer Data Link entities (DLEs) at the time of communication. These rules for communication are intended to provide a sound basis for development in order to serve a variety of purposes:

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

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

0.2 Nomenclature for references within this standard

Clauses, including annexes, can be referenced in their entirety, including any subordinate subclauses, as “clause N” or “Annex N”, where N is the number of the clause or letter of the annex.

Subclauses can be referenced in their entirety, including any subordinate subclauses, as “N.M” or “N.M.P” and so forth, depending on the level of the subclause, where N is the number of the subclause or letter of the annex, and M, P and so forth represent the successive levels of subclause up to and including the subclause of interest.

When a clause or subclause contains one or more subordinate subclauses, the text between the clause or subclause heading and its first subordinate subclause can be referenced in its entirety as “N.0” or “N.M.0” or “N.M.P.0” and so forth, where N, M and P are as above. Stated differently, a reference ending with “.0” designates the text and figures between a clause or subclause header and its first subordinate subclause.

NOTE This nomenclature provides a means of referencing text in hanging clauses. Such clauses existed in earlier editions of this standard. Some of those hanging clauses are maintained in this edition to minimize the disruption to existing national and multi-national standards and consortia documents which reference that prior subclause numbering.

DIGITAL DATA COMMUNICATIONS FOR MEASUREMENT AND CONTROL – FIELDBUS FOR USE IN INDUSTRIAL CONTROL SYSTEMS –

Part 4: Data Link protocol specification

1 Scope and object

1.1 Overview

The Fieldbus Data Link Layer provides basic time-critical messaging communications between devices in an automation environment.

The purpose of this part of IEC 61158 is to define eight distinct and non-interoperable fieldbus Data Link protocols. Each protocol defined in this part of this standard is most closely related to, and lies within the field of application of, the corresponding services of IEC 61158-3, the fieldbus Data Link Service Definition. The eight distinct protocols are the following:

Type 1 — A DL-protocol for the Type 1 DL-service. The maximum system size is 56k links of 232 nodes, each with 240 DLSAP-addresses and related peer and publisher DLCEPs, plus another 768 link-wide group DL-addresses per link, plus another 256 DLSAP-addresses and 2816 peer and publisher DLCEPs per link which can be allocated among the link's nodes, plus 2^{27} group DL-addresses for the extended link. Fewer links or nodes permits an increase in the number of DLSAP-addresses and related DLCEPs.

Type 2 — A DL-protocol for the Type 2 DL-service. The maximum system size is an unlimited number of links of 99 nodes, each with 255 DLSAP-addresses. Each link has a maximum of 2^{24} related peer and publisher DLCEPs.

Type 3 — A DL-protocol for the Type 3 DL-service. The maximum system size is an unlimited number of links of 127 nodes, each with 66 DLSAP-addresses.

Type 4 — A DL-protocol for the Type 4 DL-service. The maximum system size is a single link with a virtually unlimited number of nodes, each with 256 DLSAP-addresses connected to a single DLS-user.

Type 5 — A second DL-protocol for the Type 1 DL-service. The maximum system size for this protocol is 240 links of 240 nodes, each with 2^{16} DLSAP-addresses and related peer and publisher DLCEPs, plus another 2^{27} link-wide group DL-addresses per link, plus 2^{27} group DL-addresses for the extended link. A normative specification of this protocol was not available at the time of compilation of this edition.

Type 6 — A DL-protocol for the Type 6 DL-service. The maximum system size is a six-deep hierarchy of bridges for a total of 240^6 links, each of 240 nodes, where each node has 240 DLSAP-addresses and over 60k related peer and publisher DLCEPs, plus 16 group-DL-addresses and 4k peer and publisher DLCEPs per link which can be allocated among the link's nodes, plus a very large number of group DL-addresses for each hierarchical subtree of the extended link.

Type 7 — A DL-protocol for the Type 7 DL-service. The maximum system size is 126 links of 256 nodes, each with 16 DLSAP-addresses and 16 group DL-addresses, plus another 28k DLSAP-addresses and related peer and publisher DLCEPs per link which can be allocated among the link's nodes, plus another 28k link-wide group DL-addresses per link, plus 2^{23} group DL-addresses for the extended link.

Type 8 — A DL-protocol for the Type 8 DL-service. The maximum system size is 1 link of 256 nodes with preconfigured DLCEPs.

1.2 Specifications

This standard specifies:

- a) procedures for eight distinct and largely-incompatible protocols 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 Data Link (DL) Protocol Data Units used for the transfer of data and control information by each of those eight protocols, and their representation as Physical Interface Data Units.

NOTE Throughout IEC 61158-4, gray boxes have been used in the tables to indicate that the specified field is not a conceptual part of the specific DLPDU.

1.2.1 Type 1: Additional characteristics

This protocol provides communication opportunities to all participating data-link entities

- a) in a cyclic asynchronous manner, sequentially to each of those data-link entities, and
- b) in a synchronous manner, either cyclically or acyclically, according to a pre-established schedule.

The specified protocol also provides means of changing the set of participating data-link entities and of modifying the set of scheduled communications opportunities. When the set of scheduled communications opportunities is null, the distribution of communication opportunities to the participating data-link entities is completely asynchronous.

Thus this protocol can be characterized as one which provides access asynchronously but with a synchronous overlay.

1.2.2 Type 2: Additional characteristics

This protocol provides communication opportunities to all participating data-link entities, sequentially and in a cyclic synchronous manner. Foreground scheduled access is available for time-critical activities together with background unscheduled access for less critical activities.

Deterministic and synchronized transfers can be provided at cyclic intervals up to 1 ms and device separations of 25 km. This performance is adjustable dynamically and on-line by re-configuring the parameters of the local link whilst normal operation continues. By similar means, DL-connections and new devices may be added or removed during normal operation.

This protocol provides means to maintain clock synchronization across an extended link with a precision better than 10 μ s.

This protocol optimizes each access opportunity by concatenating multiple DLSDUs and associated DLPDI into a single DLPDU, thereby improving data transfer efficiency for data-link entities that actively source multiple streams of data.

1.2.3 Type 3: Additional characteristics

This protocol provides communication opportunities to a pre-selected “master” subset of data-link entities in a cyclic asynchronous manner, sequentially to each of those data-link entities. Other data-link entities communicate only as permitted and delegated by those master data-link entities.

For a given master, its communications with other data-link entities can be cyclic, or acyclic with prioritized access, or a combination of the two.

This protocol provides a means of sharing the available communication resources in a fair manner. There are provisions for time synchronization and for isochronous operation.

1.2.4 Type 4: Additional characteristics

This protocol provides a means of connecting devices through a partial mesh network, such that most failures of an interconnection between two devices can be circumvented. In common practice the devices are interconnected in a non-redundant hierarchical manner reflecting application needs

1.2.5 Type 5: Additional characteristics

This protocol is an adaptation of the Type 1 protocol for a PhL consisting of high-speed counter-rotating prioritized buffer insertion rings. It provides the identical Type 1 DL-service. The Type 1 and Type 5 protocols are interconnectable through bridges, seamlessly providing the entire Type 1 DL-service. These bridges forward Type 1 DLPDUs between Type 1 and Type 5 links without change, providing end-to-end error detection through a frame check sequence appended by the originating DLE.

This protocol is anticipated to be most appropriate for connecting complex control systems which must exchange large amounts of information. It provides means to maintain clock synchronization across an extended link with a precision better than 100 ns.

A normative specification of this protocol was not available at the time of compilation of this edition.

1.2.6 Type 6: Additional characteristics

This protocol provides a means of interchanging fixed-length input/output data and variable-length segmented messages between peer devices interconnected in a multidrop bus topology. The exchange of input/output data and selected messaging data is totally synchronous by configuration, and each exchange is unaffected by other traffic.

1.2.7 Type 7: Additional characteristics

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.

1.2.8 Type 8: Additional characteristics

This protocol provides a highly-optimized means of interchanging fixed-length input/output data and variable-length segmented messages between a single master device and a set of slave devices interconnected in a loop (ring) topology. The exchange of input/output data is totally synchronous by configuration, and is unaffected by the messaging traffic.

Devices are addressed implicitly by their position on the loop. The determination of the number, identity and characteristics of each device can be configured, or can be detected automatically at start-up.

1.3 Procedures

The procedures are defined in terms of

- a) the interactions between peer DL-entities (DLEs) through the exchange of fieldbus Data Link Protocol Data Units;
- 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 Physical 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. Clause 12 specifies profiles for the Type 1 fieldbus DL-protocol.

1.5 Conformance

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

The supplier of a Type 1 protocol implementation which is claimed to conform to this standard should complete a copy of the PICS proforma (see clause 13), including the information necessary to identify both the supplier and the implementation.

2 Normative references

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

IEC 61131-3:1993, *Programmable controllers – Part 3: Programming languages*

IEC 61158, *Digital data communications for measurement and control – Fieldbus for use in industrial control systems*

IEC 61158-2:2003, *Part 2: Digital data communications for measurement and control – Fieldbus for use in industrial control systems — Physical layer specification and service definition*

IEC 61158-3:2003, *Part 3: Digital data communications for measurement and control – Fieldbus for use in industrial control systems — Data link service definition*

- IEC 61158-5:2003, *Part 5: Digital data communications for measurement and control – Fieldbus for use in industrial control systems — Application layer service definition*
- IEC 61158-6:2003, *Part 6: Digital data communications for measurement and control – Fieldbus for use in industrial control systems — Application layer protocol specification*
- ISO/IEC 7498 (all parts), *Information technology – Open Systems Interconnection – Basic Reference Model*
- ISO/IEC 7498-1:1994, *Information technology – Open Systems Interconnection – Basic Reference Model — Basic Reference Model: The Basic Model*
- ISO/IEC 7498-3:1997, *Information technology – Open Systems Interconnection – Basic Reference Model — Basic Reference Model: Naming and addressing*
- ISO/IEC 8886:1996, *Information technology – Open Systems Interconnection – Data link service definition for Open Systems Interconnection*
- ISO/IEC 10038:1993, *Information technology – Telecommunications and information exchange between systems – Local area networks – Media Access Control (MAC) bridges*
- ISO/IEC 10731:1994, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*
- CENELEC EN 50170, *General purpose field communication system*
- CENELEC EN 50170-3-1:1996, *General purpose field communication system — Data link layer definitions*
- CENELEC EN 50170-3-7:1996, *General purpose field communication system — Network management*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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	called-DL-address	[7498-3]
3.1.2	calling-DL-address	[7498-3]
3.1.3	centralized multi-end-point-connection	[7498-1]
3.1.4	correspondent (N)-entities correspondent DL-entities (N=2) correspondent Ph-entities (N=1)	[7498-1]
3.1.5	demultiplexing	[7498-1]
3.1.6	DL-address	[7498-3]
3.1.7	DL-address-mapping	[7498-1]
3.1.8	DL-connection	[7498-1]
3.1.9	DL-connection-end-point	[7498-1]
3.1.10	DL-connection-end-point-identifier	[7498-1]
3.1.11	DL-connection-mode transmission	[7498-1]

3.1.12 DL-connectionless-mode transmission	[7498-1]
3.1.13 DL-data-sink	[7498-1]
3.1.14 DL-data-source	[7498-1]
3.1.15 DL-duplex-transmission	[7498-1]
3.1.16 DL-facility	[7498-1]
3.1.17 DL-local-view	[7498-3]
3.1.18 DL-name	[7498-3]
3.1.19 DL-protocol	[7498-1]
3.1.20 DL-protocol-connection-identifier	[7498-1]
3.1.21 DL-protocol-control-information	[7498-1]
3.1.22 DL-protocol-data-unit	[7498-1]
3.1.23 DL-protocol-version-identifier	[7498-1]
3.1.24 DL-relay	[7498-1]
3.1.25 DL-service-connection-identifier	[7498-1]
3.1.26 DL-service-data-unit	[7498-1]
3.1.27 DL-simplex-transmission	[7498-1]
3.1.28 DL-subsystem	[7498-1]
3.1.29 DL-user-data	[7498-1]
3.1.30 flow control	[7498-1]
3.1.31 layer-management	[7498-1]
3.1.32 multiplexing	[7498-3]
3.1.33 naming-(addressing)-authority	[7498-3]
3.1.34 naming-(addressing)-domain	[7498-3]
3.1.35 naming-(addressing)-subdomain	[7498-3]
3.1.36 (N)-entity	[7498-1]
DL-entity	
Ph-entity	
3.1.37 (N)-interface-data-unit	[7498-1]
DL-service-data-unit (N=2)	
Ph-interface-data-unit (N=1)	
3.1.38 (N)-layer	[7498-1]
DL-layer (N=2)	
Ph-layer (N=1)	
3.1.39 (N)-service	[7498-1]
DL-service (N=2)	
Ph-service (N=1)	

3.1.40 (N)-service-access-point DL-service-access-point (N=2) Ph-service-access-point (N=1)	[7498-1]
3.1.41 (N)-service-access-point-address DL-service-access-point-address (N=2) Ph-service-access-point-address (N=1)	[7498-1]
3.1.42 peer-entities	[7498-1]
3.1.43 Ph-interface-control-information	[7498-1]
3.1.44 Ph-interface-data	[7498-1]
3.1.45 primitive name	[7498-3]
3.1.46 reassembling	[7498-1]
3.1.47 recombining	[7498-1]
3.1.48 reset	[7498-1]
3.1.49 responding-DL-address	[7498-3]
3.1.50 routing	[7498-1]
3.1.51 segmenting	[7498-1]
3.1.52 sequencing	[7498-1]
3.1.53 splitting	[7498-1]
3.1.54 synonymous name	[7498-3]
3.1.55 systems-management	[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

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

For the purpose of this part of IEC 61158, the following definitions also apply:

3.3.1 DL-address user-request queue

multi-priority FIFO-within-priority queue, associated with a specific DL-address of a DLE, of in-process DLS-user-requests. This queue is partitioned into three disjoint sections:

1) those requests which have already been transmitted but remain available for retransmission, confirmation, or both — that is, which have not reached their maximum confirm delay and which

— are still within the DLCEP's transmit window, or

— are awaiting an acknowledging response DLPDU at the DLSAP;

2) those requests which are ready for transmission but have not been completely transmitted;

3) those requests which are either awaiting a DL-COMPEL-SERVICE request to release them for transmission, or are outside the DLCEP's transmit window, or both.

NOTE 1 Section 1 of the queue contains DLS-user requests which may have been successfully communicated to another DLS-user. Retransmission of all or part of the DLS-user data associated with these requests may be required, and can be attempted before the requests are purged from this partition (by reset or peer acknowledgment on a peer DLC; by reset or user-request timeout or the need for sequence-number reuse on a multi-peer DLC).

NOTE 2 Section 2 of the queue contains DLS-user requests which are ready for transmission, but could not have been completely communicated to another DLS-user.

NOTE 3 Section 3 of the queue can be non-empty only when the DL-scheduling-policy for the DL-address is EXPLICIT, or when the number of queued DLSDUs exceeds the DLCEP's transmit window, or both.

NOTE 4 Members of a given priority are advanced from one section to another until they are removed from the queue. (In practice, the section partitions may be moved, rather than the members.) The FIFO ordering within each priority is strictly maintained.

One such queue is associated with each DLSAP-address, each peer or publisher DLCEP-address, and each subscriber's DLCEP (which can be considered to be associated with an implicit DLCEP-address) of the DLE, and with the DLE's NODE DL-address (see 3.3.1 and 7.2.2.3)

3.3.2 DL-segment, link, local link

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

3.3.2.1 DLE unscheduled-service queue

multi-priority FIFO-within-priority queue of

a) **references** to DL-address user-request queues (see 3.3.1);

NOTE See 6.7.1.17a) for a more elaborate definition.

b) **references** to locally-scheduled active sequences (see clause 11) resulting from DL-SCHEDULE-SEQUENCE requests (see 10.4.3.1);

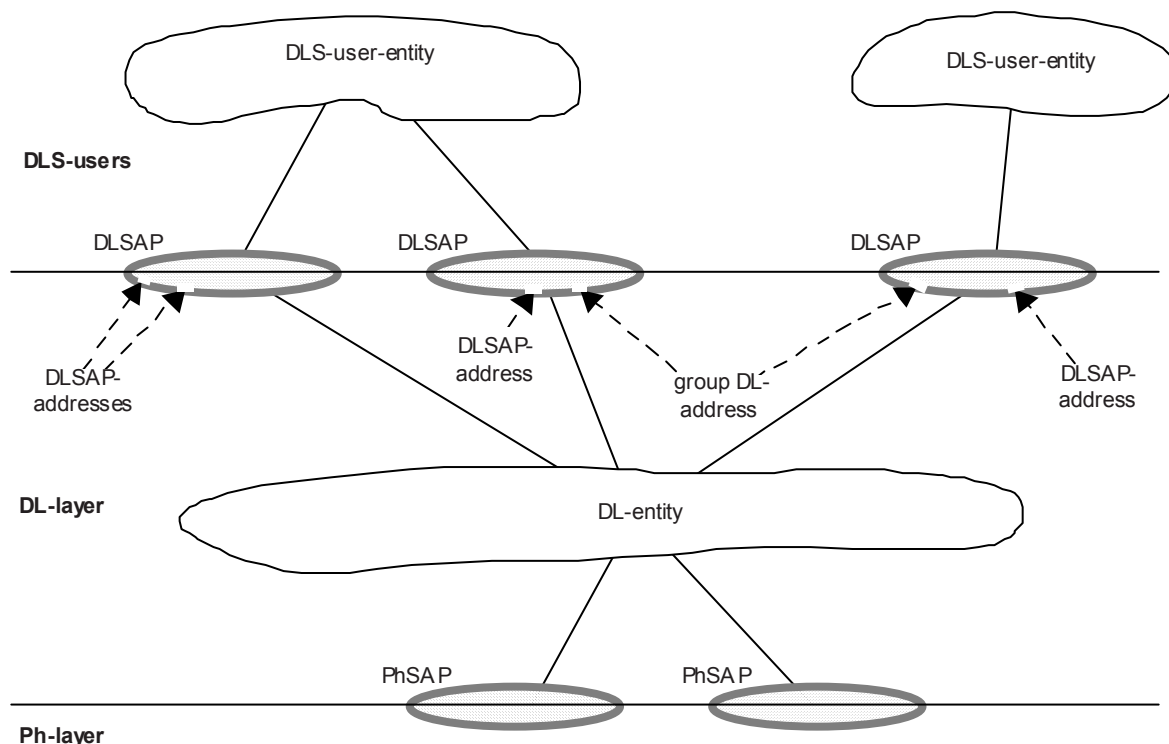
c) DT DLPDUs containing DLS-user data which are delayed responses to received CD and ED DLPDUs, queued in support of the DL-UNITDATA-EXCHANGE service

NOTE Since this is a multi-priority FIFO-within-priority queue, members are removed in priority order, and within a single priority, in FIFO order.

3.3.3 DLSAP

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

NOTE This definition, derived from ISO/IEC 7498-1, is repeated here to facilitate understanding of the critical distinction between DLSAPs and their DL-addresses. (See Figure 2.)



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

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

NOTE 3 A single DL-entity may have multiple DLSAP-addresses and group DL-addresses associated with a single DLSAP.

Figure 2 – Relationships of DLSAPs, DLSAP-addresses and group DL-addresses

3.3.4 DL(SAP)-address

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

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

3.3.5 (individual) DLSAP-address

DL-address that designates only one DLSAP within the extended link. A single DL-entity may have multiple DLSAP-addresses associated with a single DLSAP.

3.3.6 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 An extended link may be composed of just a single link

3.3.7 frame

denigrated synonym for DLPDU

3.3.8 group DL-address

DL-address that potentially designates more than one DLSAP within the extended link. A single DL-entity may have multiple group DL-addresses associated with a single DLSAP. A single DL-entity also may have a single group DL-address associated with more than one DLSAP

3.3.9 node

single DL-entity as it appears on one local link

3.3.10 receiving DLS-user

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

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

3.3.11 sending DLS-user

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

3.4 Type 1: Additional terms and definitions

NOTE For historic reasons, some of the following definitions are more extensive than is common to the Definition clauses of other IEC standards.

3.4.1 bridge, DL-router

DL-relay entity which performs selective store-and-forward and routing functions.

- a) to connect two or more separate DL-subnetworks (links) to form a unified DL-subnetwork (the extended link); and
- b) to provide a means by which two end systems can communicate, when at least one of the end systems is periodically inattentive to the interconnecting DL-subnetwork,

and also provides time synchronization among the links to which it is forwarding

3.4.2 delocalization

DLE-internal process of converting synonymous DL-addresses to a canonical form for transmission or during reception (see 7.2.2)

3.4.3 dominant token

unique right to initiate the next transmission on the local link (see token)

NOTE 1 A reply token is the dominant token on the local link during the period after its creation and before its expiration or return, and the reply token holder (the responder) holds the unique right to transmit.

NOTE 2 Otherwise, when no reply token exists, a delegated token is the dominant token on the local link during the period after its creation and before its expiration or return, and its token holder (the initiator) holds the unique right to transmit.

NOTE 3 At all other times the scheduler token is the dominant token on the local link, and the LAS DLE (which functions as the initiator) holds the unique right to transmit

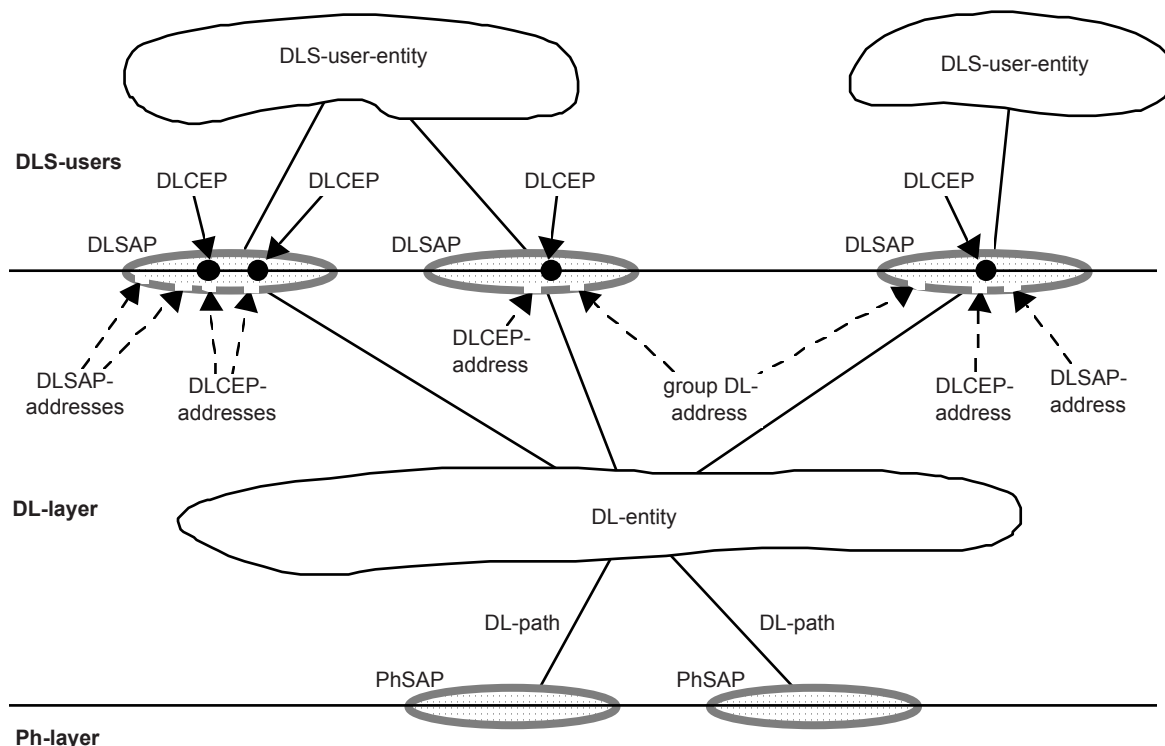
3.4.4 DLCEP-address

DL-address which designates either

- a) one peer DL-connection-end-point; or
- b) one multi-peer publisher DL-connection-end-point, and implicitly the corresponding set of subscriber DL-connection-end-points

where each DL-connection-end-point exists within a distinct DLSAP and is associated with a corresponding distinct DLSAP-address

NOTE This is an extension of the use of DL-addresses beyond that specified in ISO/IEC 7498-3. (See Figure 3.)



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

NOTE 2 DL-addresses are depicted as designating small gaps (points of access) in the DLL portion of a DLSAP. A DLCEP-address also designates a specific point of information flow (its DLCEP) within the DLSAP.

NOTE 3 A single DL-entity may have multiple DLSAP-addresses and group DL-addresses associated with a single DLSAP.

NOTE 4 This figure also shows the relationships of DL-paths and PhSAPs.

Figure 3 – Relationships of DLCEPs and DLCEP-addresses to DLSAPs, DLSAP-addresses and group DL-addresses

3.4.5 DLSEP-address

DL-address which designates a DL-scheduling-end-point within a DLE

NOTE This is an extension of the use of DL-addresses beyond that specified in ISO/IEC 7498-3.

3.4.6 fractional-duty-cycle (FDC)

DLE which is not continuously attentive to received signaling, usually found in an end-system with an austere electrical power budget

NOTE 1 Such a DLE generally requires the assistance of a bridge (DL-relay) DLE to communicate with other DLEs on the same link, to provide for cases where the two DLEs are not concurrently active.

Three classes of FDC DLE have been identified:

class A — FDC DLEs which are totally inattentive to their local links during their “sleep” periods, and control the timing of their temporary “re-awakening” to link communications solely on the basis of internal DL-time or some other measurement;

class B — FDC DLEs which monitor the link during their periods of “sleep” for a particular wakeup DLPDU (see 8.21) addressed specifically to the DLE’s node DL-address, “re-awakening” upon receipt of such a DLPDU;

class C — FDC DLEs which monitor the link during their periods of “sleep” for any DLPDUs addressed specifically to the DLE’s node DL-address, “re-awakening” upon receipt of such a DLPDU.

NOTE 2 DLEs which “sleep” between DLPDUs, but that respond to all DLPDUs addressed to any of their DL-addresses, are not FDC DLEs

3.4.7 immediate reply

DLPDU sent by the responder in a transaction as a solicited reply to the immediately-prior DLPDU

NOTE The original DLPDU sent by the initiator of the transaction specifies the constraints on the replying DLPDU.

3.4.8 immediate-response-recovery-delay

measure, similar to maximum-response-delay, of the worst-case period of **peer** PhE-inactivity which can be observed

- a) by a DLE holding a delegated token while awaiting an immediate response from another correctly-functioning DLE on the local link;
- b) by any other DLE on the local link, after receiving the initiating transaction of a two-DLPDU transaction, before detecting the link activity caused by transmission of that immediate response DLPDU;
- c) by the LAS DLE while waiting for the initial link activity after
 - a reply token (via a PROBE NODE-ADDRESS (PN) DLPDU);
 - a delegated token (via a PASS TOKEN (PT) or EXECUTE SEQUENCE (ES) DLPDU);
 - the scheduler token (via a TRANSFER LAS (TL) DLPDU)

to another correctly functioning DLE on the local link

NOTE 1 More formally, immediate-response-recovery-delay provides a bound for the worst-case delay between receipt of the Ph-Data confirm primitive for a Ph-Data request primitive whose PhIDU specified end-of-data-and-activity (see 6.4.3), and subsequent receipt of the next start-of-activity PhIDU (see 6.4.3), that can be observed by the sending DLE on the local link during

- 1) an initiator-responder interaction, in which a transaction-initiating DLE sends a DLPDU requiring an immediate reply to a responding DLE, and that responding DLE replies by sending a second DLPDU;
- 2) a token-passing interaction, in which the LAS DLE sends a delegated token DLPDU to the next intended token-holding DLE, or the scheduler token to a successor (as LAS) DLE, and that addressed DLE responds by sending a second DLPDU.

NOTE 2 The value of immediate-response-recovery-delay, in units of one slot-time, is (maximum-response-delay + 1)

3.4.9 initiator

DLE role in which a DLE sends a DLPDU to a peer responder DLE, which immediately sends a reply DLPDU back to the initiator DLE (and potentially to other DLEs) as part of the same transaction

NOTE Some prior national standards have referred to this role as a “master” role.

3.4.10 Link Active Scheduler (LAS)

special-purpose elective role of a DLE which schedules the local link and serves as the local source of DL-time for the link

NOTE The LAS functions exist within each link master (LM) DLE, which contends for and then activates those LAS functions after detecting the absence on the link of a DLE whose LAS functions are active. The DLE serving as LAS, sometimes referred to as the LAS DLE, receives, and responds to, scheduling requests from all DLEs on the link, including itself. It also receives and responds to requests for the current DL-time.

3.4.11 link-id

two-octet primary identifier for the local link, within the extended link, whose values are constrained as specified in 6.3.2.1

3.4.12 Link Master (LM)

DLE which can also provide the LAS functions for the link, including initializing and scheduling the link

3.4.12.1 maximum-inactivity-to-claim-LAS-delay

configuration parameter of each local link, its minimum value is the worst-case internal delays of any Link Master DLE and associated PhEs connected to that link

NOTE This delay is computed as the sum of the following two components:

- a) the internal delay between
 - 1) the moment of presentation of the last non-silent PhPDU of a transmission to the DLE's associated PhE at that PhE's point of connection to the local link;
 - 2) the resulting start of the DLE's internal timer which monitors link inactivity;
- b) the internal delay between
 - 1) the expiration of that timer;
 - 2) the resulting moment of presentation of the first non-silent PhPDU of a transmission of the required Claim Las (CL) DLPDU by the DLE's associated PhE at that PhE's point of connection to the local link

The unit of measurement of this aggregate delay is one eighth of the transmission period of one octet (that is, one nominal "bit-period"). The range of values of this parameter is 1 to 4 095 nominal "bit-periods"

3.4.13 maximum-response-delay

measure, in units of one slot-time, greater than the worst-case period of **local** PhE-inactivity which can be observed by a DLE

- a) which has just received a delegated token, before initiating transmission of a DLPDU;
- b) which has just received a reply token, before initiating transmission of the required immediate reply DLPDU.

NOTE 1 A DLE's minimum required value for maximum-response-delay is determined by measuring at the responding DLE the delay between concluding the reception of a requesting DLPDU and initiating the transmission of the immediately-subsequent responding DLPDU.

NOTE 2 Maximum-response-delay is a configuration parameter of each local link, and has a value of 1 to 11. When multiplied by the duration of one slot-time, the product must be at least as large as the largest of the maximum-response-delay values required by each of the current or anticipated DLEs on the local link

3.4.14 multi-peer DLC

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

NOTE 1 A multi-peer DLC always provides asymmetrical service. It may also be negotiated to provide only DL-simplex service, either from the publisher to the subscribers, or from the subscribers to the publisher. In this last case, the characterizations as publisher and subscriber are misnomers.

NOTE 2 The publishing DLS-user may need to employ control of its publishing rate, because a subscribing DLS-user cannot exert either flow or rate control on its publishing peer entity. Similar considerations apply to subscribing DLS-users with respect to their sending DLSUs to the publishing DLS-user.

3.4.15 NODE DL-address

DL-address which designates the (single) DL-entity associated with a single node (see 3.3.9) on a specific local link

3.4.16 node-id

one-octet primary identifier for the DLE on the local link, whose values are constrained as specified in 6.3.2.2. A value of zero is also permitted, which inhibits all transmission by this DLE

3.4.17 node-timer

frequency-adjustable counter, maintained by the local DLE, which is used to provide the DLS-user with a local multi-partite sense of DL-time (see 6.5.4 and 10.4.1.1) such that one component of that DL-time forms a monotonically-increasing sense of local time available for use within the attached end system

NOTE 1 Conceptually, the node-timer counts in nominal units of 2-13 ms and has a period of over 100 years. Therefore, any actual counter shall be a binary counter whose least significant bit has a nominal weight of $2^{\pm N}$ ms, with a rollover period greater than the expected maximum interval between resets of the DLE

When no information about that maximum interval is available, an interval of five years may be assumed.

NOTE 2 The node-timer is also used within the DL-protocol to provide a shared sense of DL-time which is used both to synchronize DLE scheduling actions, where appropriate, and to synchronize the rate of drift of all of the node-timers on the extended link. This latter is achieved by adjusting the frequency of each DLE's node-timer such that the DLE's monotonic sense of local time maintains an approximately constant phase relationship with that of the DLE serving as the time-reference DLE

This adjustment is the reason why the weight of the node-timer unit of counting is only nominally $2^{\pm N}$ ms

3.4.18 peer DLC

point-to-point DL-connection offering DL-duplex-transmission between two peer DLS-users where each can be a sending DLS-user, and each as a receiving DLS-user may be able to exert flow control on its sending peer

NOTE A peer DLC is negotiated to provide either symmetrical service or asymmetrical service. A peer DLC may also be negotiated to provide only DL-simplex service.

3.4.19 responder

DLE role in which a DLE sends a DLPDU as an immediate reply to a DLPDU received from a peer initiator DLE, all as part of a single transaction

NOTE Some prior national standards have referred to this role as a "slave" role.

3.4.20 slot-time

configuration parameter of each local link, measured as an integral multiple of the transmission period of one complete octet, with an integral value of between 1 and 4 095 octets:

- 1) Slot-time is a fundamental link parameter with multiple uses:
 - i) Slot-time is used by each Link Master DLE connected to the link in determining the amount of time for which that DLE monitors the link for inactivity before sending a CLAIM LAS (CL) DLPDU. Slot-time is defined such that the nominal link-inactivity monitoring periods of two DLEs which
 - have consecutive NODE DL-addresses;
 - which do not hold any tokendiffer by exactly one slot-time.
 - ii) Slot-time is used by each DLE on the local link to compute the durations of all other periods of link inactivity which the DLE must monitor. All such durations are specified as standardized or configured multiples of one slot-time.
- 2) Slot-time is a configured minimum upper bound on the maximum two-way asynchronism in immediate communications among interacting DLEs on the local link when trying to (re)initialize the link, maximized across all pairs of DLEs on that local link. Given this viewpoint, slot-time is an aggregate measure of the worst-case implementation delays within the intervening media, the PhL, and the PhL/DLL interfaces, all of which limit the rapidity of two-way DLE interaction on the local link.

Slot-time is computed as the sum of

- a) the worst-case two-way propagation delays through the intervening media and intervening PhEs, such as repeaters, between any two PhEs associated with their respective DLEs on the local link, measured between the point of connection to the local link of each of those PhEs, including worst-case internal logic and analog circuit delays in any intermediate repeaters;
- b) the maximum-inactivity-to-claim-LAS-delay as defined in 3.4.21;
- c) a safety factor, which is used to account for
 - 1) the difference in two relevant internal delays consisting of
 - i) the delay between
 - A) the presentation of the first non-silent PhPDU to the DLE's associated PhE at that PhE's point of attachment
 - B) the indication of start of activity from that PhE to that DLE;
 - ii) the delay between
 - A) the presentation of the last non-silent PhPDU to the DLE's associated PhE at that PhE's point of attachment
 - B) the indication of end of activity from that PhE to that DLE;
 - 2) the rate differences in the internal timer clocks among the DLEs on the local link;
 - 3) the limited resolution of the measurements and potential measurement errors;
 - 4) any extra delay needed to make the sum of a), b) and c) round to an integral multiple of the transmission period of one octet

NOTE 1 These delays are defined in a manner that permits their measurement.

NOTE 2 Finer resolution than one octet is not possible without knowledge of the specific associated PhL, because Ph-timing comes from the PhL and the formal PhL-DLL interface provides only octet timing (see 6.4).

NOTE 3 The definitions of 3.4.20 to 3.4.23 are not recursive, because 3.4.20 is based on a different measurement than 3.4.13 to 3.4.23. The definitions of 3.4.13 to 3.4.23 are in units of one slot-time to reduce the complexities of implementations of this protocol. As a result, a single 8-bit hardware timer, prescaled by the slot-time, enabled on bus inactivity, with usage-specific stopping and retriggering conditions, can provide the required functionality for all of the slot-time-based timers of this protocol.

3.4.21 timeliness, DL-timeliness

attribute of a datum which provides an assessment of the temporal currency of that datum. This attribute is of particular importance in sampled-data systems, which may need to make decisions based on the timeliness, or lack of timeliness, of current data samples

NOTE 1 As a general rule, timeliness is a user attribute which can be affected negatively by the various layers of the data transport system. That is, a datum which was timely when the requesting user presented it to a data communications subsystem for transmission may become untimely due to delays in the communications subsystem.

NOTE 2 DL-timeliness is an attribute of a DLS-user datum relating the timing of a DLS-user/DLE interaction which writes or reads that datum to one or more other DLS-user/DLE interactions.

NOTE 3 These concepts also support migration from previous national standards.

3.4.22 token

right to transmit on the local link

NOTE 1 This right is assumed by a DLE when it activates its LAS functions. This right may be delegated to individual DLEs, subject to specified constraints on its usage. In all cases, this right ultimately reverts to the DLE which has activated its LAS functions (the LAS DLE). Each token is implicitly qualified by the method of its transmission or assumption:

- a) A **scheduler token** is assumed and held by the LAS DLE, and can be sent to another LM DLE on the local link to transfer the activation of LAS functions to that receiving DLE.
- b) A **delegated token** is created by the LAS DLE and sent to a DLE on the local link, and is returned upon completion of its use, or assumed by the LAS DLE at its expiration.

- c) A **reply token** is created by the current delegated token holder (or scheduler token holder if there is no delegated token holder) and sent to a DLE on the local link, requesting an immediate reply; it is returned with that immediate reply, or assumed by the current delegated token holder at the expiration of the reply period

NOTE 2 It is possible, though not absolutely required, for a DLE to function simultaneously as an LAS, an initiator, and a responder, delegating a token and receiving that token, requesting an immediate reply and receiving that request, and then replying to itself as requestor and returning the token to itself as LAS. This would require the transmission of at least three DLPDUs — one from each role.

3.4.23 token-recovery-delay

measure, similar to maximum-response-delay, greater than the worst-case period of **peer** PhE-inactivity which can be observed by the LAS DLE while another correctly-functioning DLE is using a token.

NOTE 1 More formally, token-recovery-delay provides a bound greater than the worst-case delay between receipt of an end-of-activity or end-of-data-and-activity PhIDU (see 6.4.4) and subsequent receipt of the next start-of-activity PhIDU, that can be observed by any DLE on the local link during normal link operation. This delay can be exceeded only when a DLE fails while holding a delegated or scheduler token.

NOTE 2 The value of token-recovery-delay, in units of one slot-time, may be any value between (maximum-response-delay + 3) and 14

3.4.24 transaction

single DLPDU, or a sequence of two immediately consecutive related DLPDUs, resulting from a single DLS-user request

NOTE 1 The DLE sending the first DLPDU of the transaction is known as the initiator; the DLE which sends the second DLPDU of the transaction, if any, is known as the responder.

NOTE 2 A DL-entity can be both an initiator and a responder in the same transaction.

3.5 Type 2: Additional terms and definitions

3.5.1 actual packet interval (API)

measure of how frequently a specific connection produces its Lpacket data

3.5.2 allocate

take a resource from a common area and assign that resource for the exclusive use of a specific entity

3.5.3 application

function or data structure for which data is consumed or produced

3.5.4 application objects

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

3.5.5 attribute

description of an externally visible characteristic or feature of an object

NOTE The attributes of an object contain information about variable portions of an object. Typically, they provide status information or govern the operation of an object. Attributes may also affect the behavior of an object. Attributes are divided into class attributes and instance attributes.

3.5.6 behavior

indication of how the object responds to particular events. Its description includes the relationship between attribute values and services

3.5.7 bit

unit of information consisting of a 1 or a 0. This is the smallest data unit that can be transmitted

3.5.8 blanking or blanking time

length of time required after transmitting before the node is allowed to receive

3.5.9 client

- 1) An object which uses the services of another (server) object to perform a task
- 2) An initiator of a message to which a server reacts

3.5.10 communication objects

components that manage and provide run time exchange of messages across the network such as the ControlNet object, the unconnected message manager (UCMM)

3.5.11 connection

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

3.5.12 connection ID (CID)

identifier assigned to a transmission, associated with a particular connection between producers and consumers, that identifies a specific piece of application information

NOTE Within the data link this is a generic tag.

3.5.13 cyclic redundancy check (CRC)

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

3.5.14 cyclic

term used to describe events which repeat in a regular and repetitive manner

3.5.15 deafness

situation where the node can not hear the moderator DLPDU but can hear other link traffic

3.5.16 device

physical hardware connection to the link

NOTE A device may contain more than one node.

3.5.17 DLPDU

Data Link Protocol Data Unit

NOTE A DLPDU consists of a source MAC ID, zero or more Lpackets and an FCS as transmitted or received by an associated PhE.

3.5.18 end delimiter

unique set of M_symbols that identifies the end of a DLPDU

3.5.19 error

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

3.5.20 extended link

links connected by DL-routers (sometimes called a local area network)

3.5.21 FCS error

error that occurs when the computed frame check sequence value after reception of all the octets in a DLPDU does not match the expected residual

3.5.22 fixed tag

two octet identifier (tag) which identifies a specific service to be performed by either

- a) that receiving node on the local link which has a specified MAC ID, or
- b) all receiving nodes on the local link

NOTE Identification of the target node(s) is included in the two octet tag

3.5.23 frame

denigrated synonym for DLPDU

3.5.24 generic tag

three octet identifier (tag) which identifies a specific piece of application information

3.5.25 guardband

time slot allocated for the transmission of the moderator DLPDU

3.5.26 implicit token

mechanism that governs the right to transmit

NOTE No actual token message is transmitted on the medium. Each node keeps track of the MAC ID of the node that it believes currently holds the right to transmit. The right to transmit is passed from node to node by keeping a record of the node that last transmitted. A slot time is used to allow a missing node to be skipped in the rotation

3.5.27 implicit token register

register that contains the MAC ID of the node that holds the right to transmit

3.5.28 instance

actual physical occurrence of an object within a class, identifying one of many objects within the same object class

EXAMPLE California is an instance of the object class state.

NOTE The terms object, instance, and object instance are used to refer to a specific instance.

3.5.29 instance attribute

attribute that is unique to an object instance and not shared by the object class

3.5.30 instantiated

object that has been created in a device

3.5.31 keeper

object responsible for distributing link configuration data to all nodes on the link

3.5.32 link

collection of nodes with unique MAC IDs, attached to Ph-segments connected by Ph-repeaters

3.5.33 little endian

model of memory organization which stores the least significant octet at the lowest address, and of transmission organization which transfers the least significant octet first on the medium

3.5.34 Lpacket

well-defined sub-portion of a DLPDU consisting of

- a) size and control information
- b) a fixed tag or a generic tag, and
- c) DLS-user data or, when the tag has DL-significance, DL-data

3.5.35 M_symbol(s)

symbols that represent the data bits and related information encoded and transmitted by the PhL

3.5.36 maximum scheduled node

node with highest MAC ID that can use scheduled time on a link

3.5.37 maximum unscheduled node

node with highest MAC ID that can use unscheduled time on a link

3.5.38 message router

object within a node that distributes messaging requests to the appropriate application objects

3.5.39 moderator

node with the lowest MAC ID that is responsible for transmitting the moderator DLPDU

3.5.40 moderator DLPDU

DLPDU transmitted by the node with the lowest MAC ID for the purpose of synchronizing the nodes and distributing the link configuration parameters

3.5.41 multipoint connection

connection from one node to many

NOTE Multipoint connections allow messages from a single producer (publisher) to be received by many consumer (subscriber) nodes.

3.5.42 network

series of nodes connected by some type of communication medium. The connection paths between any pair of nodes can include repeaters, routers and gateways