BS EN 61158-4-1:2014

BSI Standards Publication

Industrial communication networks — Fieldbus specifications

Part 4-1: Data-link layer protocol specification — Type 1 elements

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National foreword

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

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

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Published by BSI Standards Limited 2014

ISBN 978 0 580 79372 1
ICS 25.040.40; 35.100.20; 35.110

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2014.

Amendments issued since publication

Date	Text affected

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Full document details: BS EN 61158-4-1:2014

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 61158-4-1

October 2014

ICS 25.040.40; 35.100.20; 35.110

Supersedes EN 61158-4-1:2008

English Version

Industrial communication networks - Fieldbus specifications - Part 4-1: Data-link layer protocol specification - Type 1 elements (IEC 61158-4-1:2014)

Réseaux de communication industriels - Spécifications des bus de terrain - Partie 4-1: Spécification du protocole de la couche liaison de données - Éléments de type 1 (CEI 61158-4-1:2014)

Industrielle Kommunikationsnetze - Feldbusse - Teil 4: Protokollspezifikation des Data Link Layer (Sicherungsschicht) - Typ 1-Elemente (IEC 61158-4-1:2014)

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Foreword

The text of document 65C/762/FDIS, future edition 2 of IEC 61158-4-1, prepared by IEC/TC 65C "Industrial networks" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61158-4-1:2014.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-06-19
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-09-19

This document supersedes EN 61158-4-1:2008.

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Endorsement notice

The text of the International Standard IEC 61158-4-1:2014 was approved by CENELEC as a European Standard without any modification.

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

IEC 61158-5-5:2014	NOTE	Harmonised as EN 61158-5-5:2014
IEC 61158-6-5:2014	NOTE	Harmonised as EN 61158-6-5:2014
IEC 61784-1	NOTE	Harmonised as EN 61784-1
IEC 61784-2	NOTE	Harmonised as EN 61784-2

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

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

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

Publication	Year	Title	EN/HD	Year
IEC 61158-1	2014	Industrial communication networks - Fieldbus specifications - Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series	EN 61158-1	2014
IEC 61158-2	2014	Industrial communication networks - Fieldbus specifications - Part 2: Physical layer specification and service definition	EN 61158-2	2014
IEC 61158-3-1	2014	Industrial communication networks - Fieldbus specifications - Part 3-1: Data-link layer service definition - Type 1 elements	EN 61158-3-1	2014
ISO/IEC 7498-1	-	Information technology - Open Systems Interconnection - Basic reference model: The basic model	-	-
ISO/IEC 7498-3	-	Information technology - Open Systems Interconnection - Basic reference model: Naming and addressing	-	-
ISO/IEC 8886	-	Information technology - Open Systems Interconnection - Data link service definition	-	-
ISO/IEC 10038	1993	Information technology - Telecommunications and information exchange between systems - Local area networks - Media Access Control (MAC) bridges	-	-
ISO/IEC 10731	-	Information technology - Open Systems Interconnection - Basic Reference Model - Conventions for the definition of OSI services	-	-

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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 described in IEC 61158-1.

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

a) as a guide for implementors and designers;

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

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

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

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

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 IEC 61784-3, Type 1 clauses. 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.

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-1: Data-link layer protocol specification – Type 1 elements

1 Scope

1.1 General

The data-link layer provides basic time-critical messaging communications between devices in an automation environment.

This protocol provides 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 described in IEC 61158-1.

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 Specifications

This standard specifies

a) procedures for the timely transfer of data and control information from one data-link user entity to a peer user entity, and among the data-link entities forming the distributed data-link service provider;

b) the structure of the fieldbus DLPDUs used for the transfer of data and control information by the protocol of this standard, and their representation as physical interface data units.

NOTE In IEC 61158-4-1, gray boxes have been used in the tables to indicate that the specified field is not a conceptual part of the specific DLPDU.

1.3 Procedures

The procedures are defined in terms of

a) the interactions between peer DL-entities (DLEs) through the exchange of fieldbus DLPDUs;

b) the interactions between a DL-service (DLS) provider and a DLS-user in the same system through the exchange of DLS primitives;

c) the interactions between a DLS-provider and a Ph-service provider in the same system through the exchange of Ph-service primitives.

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1.4 Applicability

These procedures are applicable to instances of communication between systems which support time-critical communications services within the data-link layer of the OSI or fieldbus reference models and which require the ability to interconnect in an open systems interconnection environment.

Profiles provide a simple multi-attribute means of summarizing an implementation's capabilities, and thus its applicability to various time-critical communications needs.

1.5 Conformance

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

2 Normative references

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

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

IEC 61158-1:2014, *Industrial communication networks – Fieldbus specifications – Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series*

IEC 61158-2:2014, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 61158-3-1:2014, *Industrial communication networks – Fieldbus specifications – Part 3-1: Data link service definition – Type 1 elements*

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

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

ISO/IEC 8886, *Information technology – Open Systems Interconnection – Data link service definition*

ISO/IEC 10038:1993, *Information technology – Telecommunications and information exchange between systems – Local area networks – Media access control (MAC) bridges*

NOTE This edition has been withdrawn and replaced by ISO/IEC 15802-3:1998. However, the detailed references in this standard are to the 1993 edition.

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

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3 Terms, definitions, symbols and abbreviations

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

3.1 Reference model terms and definitions

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

3.1.1 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 [7498-1]
correspondent DL-entities (N=2)
correspondent Ph-entities (N=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]

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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 [7498-1]
DL-service-access-point (N=2)
Ph-service-access-point (N=1)

3.1.41 (N)-service-access-point-address [7498-1]
DL-service-access-point-address (N=2)
Ph-service-access-point-address (N=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]

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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 Terms and definitions

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

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3.3.1
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

3.3.2
delocalization
DLE-internal process of converting synonymous DL-addresses to a canonical form for transmission or during reception (see 5.2.2)

3.3.3
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 partitioned into three disjoint sections:

a) 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;

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

c) 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 to entry: 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 to entry: 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 to entry: 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 to entry: 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.

Note 5 to entry: 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 5.2.2.3).

3.3.4
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

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3.3.5
DLE unscheduled-service queue

multi-priority FIFO-within-priority queue of

a) references to DL-address user-request queues (see 3.3.3);

b) references to locally-scheduled active sequences (see Clause 11) resulting from DL-SCHEDULE-SEQUENCE requests (see 8.4.3.1);

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 1 to entry: See 4.7.1.17 a) for a more elaborate definition.

Note 2 to entry: Since this is a multi-priority FIFO-within-priority queue, members are removed in priority order, and within a single priority, in FIFO order.

3.3.6
DLSAP
distinctive point at which DL-services are provided by a single DL-entity to a single higher-layer entity

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

3.3.7
DL(SAP)-address
either an individual DLSAP-address, designating a single DLSAP of a single DLS-user, or a group DL-address potentially designating multiple DLSAPs, each of a single DLS-user

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

3.3.8
(individual) DLSAP-address
DL-address that designates only one DLSAP within the extended link

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

3.3.9
DLCEP-address
DL-address which designates either

a) one peer DL-connection-end-point; or

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

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

Note 1 to entry: This is an extension of the use of DL-addresses beyond that specified in ISO/IEC 7498-3. (See Figure 1.)

3.3.10
DLSEP-address
DL-address which designates a DL-scheduling-end-point within a DLE

Note 1 to entry: This is an extension of the use of DL-addresses beyond that specified in ISO/IEC 7498-3.

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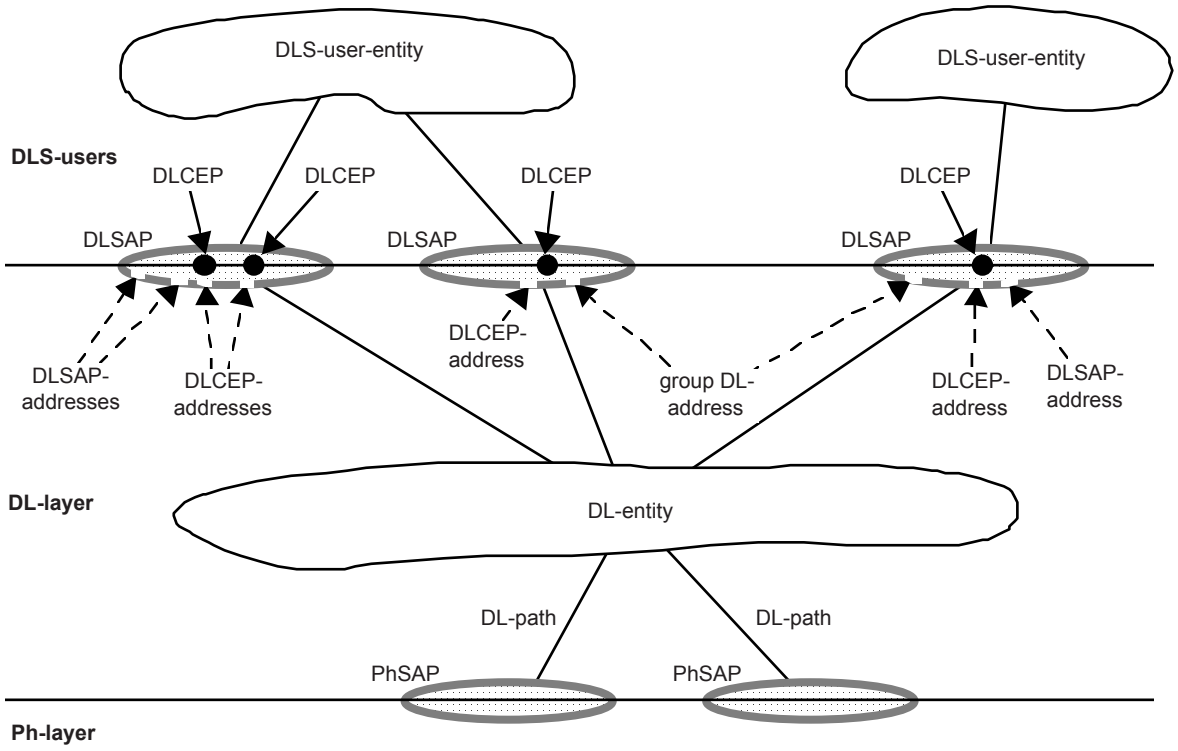

NOTE 1 DLSAPs and PhSAPs are depicted as ovals spanning the boundary between two adjacent layers.

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 1 – Relationships of DLSAPs, DLSAP-addresses, DLCEPs, DLCEP-addresses, DLSEP-addresses and group DL-addresses

3.3.11
dominant token
unique right to initiate the next transmission on the local link (see token)

Note 1 to entry: 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 to entry: 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 to entry: 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

3.3.12
extended link
DL-subnetwork, consisting of the maximal set of links interconnected by DL-relays, sharing a single DL-name (DL-address) space, in which any of the connected DL-entities may communicate, one with another, either directly or with the assistance of one or more of those intervening DL-relay entities

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

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3.3.13
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 to entry: 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 6.21) 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 to entry: DLEs that "sleep" between receipt of DLPDUs, but that respond to all DLPDUs addressed to any of their DL-addresses, are not FDC DLEs.

3.3.14
frame
denigrated synonym for DLPDU

3.3.15
group DL-address
DL-address that potentially designates more than one DLSAP within the extended link

Note 1 to entry: A single DL-entity can have multiple group DL-addresses associated with a single DLSAP. A single DL-entity also can have a single group DL-address associated with more than one DLSAP

3.3.16
immediate reply
DLPDU sent by the responder in a transaction as a solicited reply to the immediately prior DLPDU

Note 1 to entry: The original DLPDU sent by the initiator of the transaction specifies the constraints on the replying DLPDU.

3.3.17
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 to entry: 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-

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data-and-activity (see 4.4.3), and subsequent receipt of the next start-of-activity PhIDU (see 4.4.3), 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 to entry: The value of immediate-response-recovery-delay, in units of one slot-time, is (maximum-response-delay + 1).

3.3.18
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 1 to entry: Some prior national standards have referred to this role as a “master” role.

3.3.19
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 1 to entry: 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.

3.3.20
link-id
two-octet primary identifier for the local link, within the extended link, whose values are constrained as specified in 4.3.2.1

3.3.21
Link Master
LM
DLE which can also provide the LAS functions for the link, including initializing and scheduling the link

3.3.20.1
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 1 to entry: 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”.

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3.3.22
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 to entry: 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 to entry: 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.

3.3.23
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 to entry: 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 to entry: 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 DLSDUs to the publishing DLS-user.

3.3.24
node
single DL-entity as it appears on one local link

3.3.25
NODE DL-address
DL-address which designates the (single) DL-entity associated with a single node (see 3.3.23) on a specific local link

3.3.26
node-id
one-octet primary identifier for the DLE on the local link, whose values are constrained as specified in 4.3.2.2

Note 1 to entry: A value of zero is also permitted, which inhibits all transmission by this DLE.

3.3.27
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 4.5.4 and 8.4.1.1) 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 to entry: 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±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 to entry: 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

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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.

3.3.28
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 1 to entry: 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.

3.3.29
receiving DLS-user
DL-service user that acts as a recipient of DL-user-data

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

3.3.30
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 1 to entry: Some prior national standards have referred to this role as a "slave" role.

3.3.31
sending DLS-user
DL-service user that acts as a source of DL-user-data

3.3.32
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:

Note 1 to entry: Slot-time is a fundamental link parameter with multiple uses:

- 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 and which do not hold any token differ by exactly one slot-time.
- 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.
- 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 3.3.32;

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,

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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.

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

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 4.4).

The definitions of 3.3.31 to 3.3.34 are not recursive, because 3.3.31 is based on a different measurement than 3.3.21 to 3.3.34. The definitions of 3.3.21 to 3.3.34 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.

3.3.33
timeliness
DL-timeliness
attribute of a datum which provides an assessment of the temporal currency of that datum

Note 1 to entry: 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 2 to entry: 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 3 to entry: 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 4 to entry: These concepts also support migration from previous national standards.

3.3.34
token
right to transmit on the local link

Note 1 to entry: 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 to entry: 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.

3.3.35
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

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Note 1 to entry: 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 4.4.4) 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 to entry: The value of token-recovery-delay, in units of one slot-time, may be any value between (maximum-response-delay + 3) and 14.

3.3.36
transaction
single DLPDU, or a sequence of two immediately consecutive related DLPDUs, resulting from a single DLS-user request

Note 1 to entry: 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 to entry: A DL-entity can be both an initiator and a responder in the same transaction.

3.4 Symbols and abbreviations

3.4.1 Data units

3.4.1.1	**BPDU**	bridge protocol data unit, used in the ISO/IEC 10038 inter-bridge protocol
3.4.1.2	**pDLSDU**	partial DL-service data unit – one segment of a multi-segment DLSDU
3.4.1.3	**SPDU**	support protocol data unit, used to support the full DL-protocol

3.4.2 Local variables, timers, counters and queues

3.4.2.1	**V(ST)**	slot time	See 4.7.1.1
3.4.2.2	**V(PhLO)**	per DLPDU PhL overhead	See 4.7.1.2
3.4.2.3	**V(MRD)**	maximum response delay	See 4.7.1.3
3.4.2.4	**V(IRRD)**	immediate response recovery delay	See 4.7.1.4
3.4.2.5	**V(MRC)**	maximum retry count	See 4.7.1.5
3.4.2.6	**V(NRC)**	network retry count	See 4.7.1.6
3.4.2.7	**V(NDL)**	network DLPDU lifetime	See 4.7.1.7
3.4.2.8	**V(TN)**	this node	See 4.7.1.8
3.4.2.9	**V(TL)**	this link	See 4.7.1.9
3.4.2.10	**V(MEP)**	DL MAC address embedding prefix	See 4.7.1.10
3.4.2.11	**C(RD)**	remaining duration down-counter	See 4.7.1.11
3.4.2.12	**V(MID)**	minimum inter-DLPDU delay	See 4.7.1.12
3.4.2.13	**T(IRRD)**	immediate response recovery delay monitor	See 4.7.1.13
3.4.2.14	**V(RA)**	reply address	See 4.7.1.14
3.4.2.15	**V(OTA)**	outstanding transaction array	See 4.7.1.15
3.4.2.16	**V(LTI)**	last transaction index	See 4.7.1.16
3.4.2.17	**Q(US)**	unscheduled service queue	See 4.7.1.17

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3.4.2.18	**V(RID)**	random identifier	See 4.7.1.18
3.4.2.19	**C(NT)**	node time up-counter	See 4.7.1.19
3.4.2.20	**V(LSTO)**	local link scheduling time offset	See 4.7.1.20
3.4.2.21	**V(DLTO)**	DL-time offset	See 4.7.1.21
3.4.2.22	**V(TQ)**	time quality	See 4.7.1.22
3.4.2.23	**V(MD)**	measured delay	See 4.7.1.23
3.4.2.24	**V(LN)**	LAS node	See 4.7.1.24
3.4.2.25	**V(TSC)**	time synchronization class	See 4.7.1.25
3.4.2.26	**T(TDP)**	time distribution period monitor	See 4.7.1.26
3.4.2.27	**V(TSL)**	time source link	See 4.7.1.27
3.4.2.28	**P_U(SDUL)**	DLSDU length request parameter	See 4.7.2.1
3.4.2.29	**P_U(SDU)**	DLSDU request parameter	See 4.7.2.2
3.4.2.30	**P_U(MCD)**	maximum confirm delay parameter	See 4.7.2.3
3.4.2.31	**T_U(MCD)**	maximum confirm delay monitor	See 4.7.2.4
3.4.2.32	**Q_A(UR)**	user request queue	See 4.7.3.1
3.4.2.33	**V_C(ST)**	DLCEP state	See 4.7.4.1
3.4.2.34	**V_C(NP)**	negotiated DLCEP parameters	See 4.7.4.2
3.4.2.35	**V_C(N)**	next sequence number to assign to a DLSDU	See 4.7.4.3
3.4.2.36	**V_C(R)**	maximum non-transmittable DLSDU sequence number	See 4.7.4.4
3.4.2.37	**V_C(A)**	maximum acknowledged DLSDU sequence number	See 4.7.4.5
3.4.2.38	**V_C(M)**	minimum untransmitted DLSDU sequence number	See 4.7.4.6
3.4.2.39	**V_C(MS)**	minimum untransmitted segment number	See 4.7.4.7
3.4.2.40	**$V_{C,K}$(SS)**	to-be-sent segments of a DLSDU	See 4.7.4.8
3.4.2.41	**$T_{C,K}$(SS)**	sent segments monitor for a DLSDU	See 4.7.4.9
3.4.2.42	**T_C(SS)**	simplified sent segments monitor for a DLSDU	See 4.7.4.9.1
3.4.2.43	**V_C(L)**	last reported DLSDU sequence number	See 4.7.4.10
3.4.2.44	**V_C(H)**	highest detected DLSDU sequence number	See 4.7.4.11
3.4.2.45	**V_C(HS)**	highest detected segment number of the highest detected DLSDU sequence number	See 4.7.4.12
3.4.2.46	**$V_{C,K}$(MRS)**	missing received segments of a DLSDU	See 4.7.4.13

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3.4.2.47	**$V_{C,K}$(RRS)**	retransmission request required segments of a DLSDU	See 4.7.4.14
3.4.2.48	**$T_{C,K}$(RRS)**	retransmission request monitor for a DLSDU	See 4.7.4.15
3.4.2.49	**T_C(RAS)**	residual activity stimulus	See 4.7.4.16
3.4.2.50	**T_C(RAM)**	residual activity monitor	See 4.7.4.17
3.4.2.51	**V_C(TNA)**	DL-time of last network access	See 4.7.4.18
3.4.2.52	**V_B(TW)**	DL-time of last buffer write	See 4.7.4.19
3.4.2.53	**V_B(TP)**	DL-time of production	See 4.7.4.20
3.4.2.54	**V_B(TS)**	timeliness status of buffer write	See 4.7.4.21
3.4.2.55	**V(DTA)**	delegation address	See 4.7.5.1
3.4.2.56	**V(LL)**	local link live list	See 4.7.5.2
3.4.2.57	**V(TCL)**	token circulation list	See 4.7.5.3
3.4.2.58	**V(ENRL)**	expected non-response list	See 4.7.5.4
3.4.2.59	**V(MST)**	maximum scheduled traffic	See 4.7.5.5
3.4.2.60	**V(MSO)**	maximum scheduling overhead	See 4.7.5.6
3.4.2.61	**V(DMDT)**	default minimum token delegation time	See 4.7.5.7
3.4.2.62	**V(DTHT)**	default token holding time	See 4.7.5.8
3.4.2.63	**V(LTHT)**	link maintenance token holding time	See 4.7.5.9
3.4.2.64	**V(MTHA)**	maximum token holding time array	See 4.7.5.10
3.4.2.65	**V(TTRT)**	target token rotation time	See 4.7.5.11
3.4.2.66	**V(ATRT)**	actual token rotation time	See 4.7.5.12
3.4.2.67	**V(RTHA)**	remaining token holding time array	See 4.7.5.13
3.4.2.68	**V(NTHN)**	next token holding node	See 4.7.5.14
3.4.2.69	**V(FUN)**	first unpolled node id	See 4.7.5.15
3.4.2.70	**V(NUN)**	number of consecutive unpolled node ids	See 4.7.5.16
3.4.2.71	**P(TRD)**	token recovery delay	See 4.7.5.17
3.4.2.72	**V(TDP)**	time distribution period	See 4.7.5.18
3.4.2.73	**V(MICD)**	maximum inactivity to claim LAS delay	See 4.7.5.19
3.4.2.74	**V(LDDP)**	LAS data base distribution period	See 4.7.5.20
3.4.2.75	**V(ML)**	maximum link	See 4.7.6.1

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3.4.3 DLPDU classes

3.4.3.1	**CA**	compel acknowledgment	See 6.4
3.4.3.2	**CD**	compel data	See 6.5
3.4.3.3	**CL**	claim LAS	See 6.19
3.4.3.4	**CT**	compel time	See 6.9
3.4.3.5	**DC**	disconnect connection	See 6.2
3.4.3.6	**DT**	data	See 6.7
3.4.3.7	**EC**	establish connection	See 6.1
3.4.3.8	**ED**	exchange data	See 6.6
3.4.3.9	**ES**	execute sequence	See 6.16
3.4.3.10	**IDLE**	idle	See 6.22
3.4.3.11	**PN**	probe node address	See 6.13
3.4.3.12	**PR**	probe return	See 6.14
3.4.3.13	**PT**	pass token	See 6.15
3.4.3.14	**RC**	reset connection	See 6.3
3.4.3.15	**RI**	request interval	See 6.18
3.4.3.16	**RQ**	round trip delay query	See 6.11
3.4.3.17	**RR**	round trip delay reply	See 6.12
3.4.3.18	**RT**	return token	See 6.17
3.4.3.19	**SR**	status response	See 6.8
3.4.3.20	**TD**	time distribution	See 6.10
3.4.3.21	**TL**	transfer LAS	See 6.20
3.4.3.22	**WK**	wakeup	See 6.21

3.4.4 Miscellaneous

3.4.4.1	**BME**	bridge management entity
3.4.4.2	**DLC**	DL-connection
3.4.4.3	**DLP-**	DL-protocol (as a prefix)
3.4.4.4	**DLPCI**	data link protocol control information
3.4.4.5	**DLSEP**	DL-schedule endpoint
3.4.4.6	**FC**	frame control (first octet of each DLPDU)
3.4.4.7	**FDC**	fractional duty cycle (type of DLE)
3.4.4.8	**LAS**	link active scheduler
3.4.4.9	**LM**	link master

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3.4.4.10 PhICI physical interface control information

3.4.4.11 PhID physical interface data

3.4.4.12 SLAE systems load application entity

3.4.4.13 SMAE systems management application entity

4 Overview of the DL-protocol

4.1 Three-level model of the DLL

The DLL is modeled as

a) a low-level of path-access-and-scheduling functions, which supports,

b) an intermediate-level of bridge-operation functions, which in turn supports,

c) a higher-level of connection-mode and connectionless data transfer, bridge-coordination, and DL-service functions.

Interoperating with all three levels are DL-management functions, including bridge and redundant-path management functions where relevant.

NOTE 1 The term “sublayer” is not appropriate for describing these levels, since ISO/IEC 7498 requires that when multiple sublayers are defined, all but one of them must be optional.

NOTE 2 This three-level partitioning closely resembles the partitioning into lower-level “MAC”, intermediate-level “bridge-operation”, and higher-level “LLC” functions found in the ISO/IEC LAN standards (see ISO/IEC TR 8802-1 for the MAC service definition), with the following two significant differences.

a) This protocol’s low-level functionality is contained entirely within the Data Link layer as specified by ISO/IEC 7498. In contrast, the “MAC’ functionality of the ISO/IEC LAN protocols spans the lower part of the OSI Data Link Layer and the upper part of the OSI Physical Layer.

b) This protocol employs a single level of DL-addressing within the Data Link layer. In contrast, the ISO/IEC LAN protocols employ two levels of DL-addressing, one within the “MAC” and “bridge-operation” functionality and a second within the “LLC” functionality.

4.1.1 Path access and scheduling level

The path-access-and-scheduling level provides basic communication from one DLE to another. The timing of such communication is regulated

a) to provide an equitable distribution of opportunities for arbitrary communications to all DLEs on the local link, generally in a cyclic but asynchronous manner;

b) to provide a specific distribution of opportunities for designated communications to DLEs on the local link in accord with a pre-established schedule for the link.

It is the latter requirement for scheduled communications, in support of time-critical communications, which causes this protocol to rely more heavily on centralized real-time management of the communications opportunities than prior protocols such as ISO/IEC 8802-3, ISO/IEC 8802-4 and ISO/IEC 8802-5. The centralized manager is elected from the set of operating full-function DLEs on the local link by a procedure similar to that used in ISO/IEC 8802-4 and ISO/IEC 8802-5. Should that manager fail, a replacement is similarly elected.

NOTE Many traditional control algorithms used in the domain of applicability of this protocol require tight constraints on the cycle-to-cycle timing of information acquisition. In distributed systems such constraints frequently translate to limits on the permissible cycle-to-cycle periodicity of the messaging which conveys that repetitively acquired information.

c) The path-access-and-scheduling level forms each DLPDU from DL-protocol control information and DLS-user data; computes and appends an appropriate frame check sequence (FCS); and passes the whole as a sequence of PhIDUs (see 4.4) to the PhE for transmission to peer PhEs for reporting to peer DLEs.

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In some cases it also appends the low-order three octets either

– of the current value of the local node-timer, C(NT); or
– of a computed value minus the current value of the local node-timer, C(NT),

during DLPDU formation, immediately preceding the appended FCS.

d) The path-access-and-scheduling level receives a sequence of PhIDUs from the PhE, concatenates those PhIDUs into a received DLPDU, computes a frame check sequence over the entire sequence of received data, and checks for the proper residual value. The first octet of the received sequence is examined to determine the type of the DLPDU, and an attempt is made to parse that DLPDU into its DL-protocol control information and DLS-user data components. If the FCS residual was correct and the parse was successful, then the appropriate low-level actions are performed, possibly including reporting the parsed DLPDU to a higher level.

   In some cases the value of the low-order three octets of the local node-timer, C(NT), at the time of receipt, is appended to this parsed DLPDU.

e) The path-access-and-scheduling level provides the basic functions of both responder and initiator. As a responder, it provides the sequencing functions necessary

   1) for receiving a DLPDU, possibly conveying a reply token;
   2) in that latter case (of the received reply token), for sending a DLPDU as an immediate reply to the just-received DLPDU.

   As an initiator, it provides the sequencing functions necessary for

   3) receiving a delegated token;
   4) sending one or more DLPDUs, including those requiring an immediate reply;
   5) receiving such an immediate reply, or inferring its absence;
   6) returning a delegated token.

f) The path-access-and-scheduling level provides the low-level scheduling functionality required for scheduling DLPDU transmissions on a specific path, including any interactions with the local link's link active scheduler (LAS) to coordinate the schedule with other DLEs or to request needed path transmission capacity.

The actions of c) and d) are augmented within a bridge relay DLE) to permit the retransmission of a received sequence of data octets, including the received FCS, with possible constrained alterations of the first octet and compensating alterations (see 5.2.5.3) of the received FCS, prior to retransmission.

The actions of e) and f) are based in part on two request-management and scheduling queues:

- a DL-address-specific request queue see 3.3.3), associated with the sending address, which is used to manage DLS-user requests originated from that DL-address;
- the common DLE unscheduled-service queue see 4.7.1.17), which is used to manage the servicing of unscheduled requests upon receipt of the "circulated" token.

Some of the more complex scheduling functionality of this level requires, and uses, the services of the upper level, see 4.1.3) by acting as a DLE-internal quasi-DLS-user.

4.1.2 Bridge-operation level

The bridge-operation level provides the intermediate-level functionality of

a) logically inter-connecting multiple local links into a single extended-link by physically interconnecting multiple paths;
b) serving as a possibly-distributed "time-space-time" switch:

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1) providing DLPDU store-and-forward functions to permit communication between DLEs on the extended link which could not otherwise communicate;

NOTE This includes the coordination with fractional-duty-cycle FDC) DLEs (see 3.3.32) necessary to permit alternating periods of "FDC-DLE-awake' and "FDC-DLE-asleep" operation.

2) providing surrogate functions to permit delayed-reply interactions between DLEs on the extended link as an extrapolation of "immediate-reply" transactions on a local link;

c) providing a shared sense of DL-time throughout the extended link;

d) coordinating local-link scheduling among two or more local links to provide any necessary multi-link coordination of scheduling within the extended link.

Much of the bridge-operation level of functionality is active only in "bridge" DLEs (see 4.6).

4.1.3 Connection-mode and connectionless data transfer, bridge-coordination, and DL-service level

The connection-mode and connectionless data transfer, bridge-coordination, and DL-service level provides the higher-level functionality of

a) managing all DLE interactions with the DLS-user, converting all DLS-user request and response primitives into the necessary sequence of DLE operations, and generating DLS-user indication and confirm primitives where appropriate;

b) managing the sequencing of each active DLCEP, including

1) determination of the type and sequence of DLPDUs to be transmitted from the DLCEP;

2) QoS negotiation;

3) determination of the DLPCI to be included in each DLPDU;

4) segmentation and reassembly of large DLSDUs;

c) managing the sequencing of unitdata transactions which require a response from a peer DLE, including

1) determination of the DLPCI to be included in each DLPDU;

2) correlation of a non-immediate reply DLPDU with the requesting transaction;

d) processing all inter-DLE state-information-distribution DLPDUs, such as TIME DISTRIBUTION (TD) (see 6.10 and 8.4.1) and bridge configuration (see 10.4) DLPDUs and LAS-backup SPDUs (see Clause 9);

e) managing all query-DLPDU/reply-DLPDU interactions with other DLEs, other than those which occur as an "immediate reply" and which are made on a reactive basis by the lower-level functions of 4.1.1.

These query-DLPDU / reply-DLPDU interactions also include computation of round-trip-delays (see 6.11, 6.12, and 8.4.1), support of remotely-initiated DL-SUBSCRIBER-QUERY (see 8.2.3) and DL-LISTENER-QUERY (see 8.3.4) requests, and inter-bridge exchanges of bridge state information (see 10.4).

4.2 Service provided by the DLL

The DLL provides connectionless data transfer services for limited-size DLSDUs, connection-mode data transfer services for limited-size DLSDUs, an internally synchronized time service, scheduling services to control the time allocation of the underlying shared PhL service, and a DL(SAP)-address, queue and buffer management service.

NOTE IEC 61158-3-1 shows many of the relationships among DLC QoS attributes.

Some relevant QoS attributes are as follows:

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4.2.1 QoS – DLCEP class

Each DLCEP establishment request specifies the class of the DLCEP. The three choices for DLCEP-class are

a) **PEER** – the DLS-user can exchange DLSDUs with one other peer DLS-user;

b) **PUBLISHER** – the DLS-user can send DLSDUs to a set of zero or more associated subscribing DLS-users, and receive DLSDUs from any of those subscribing DLS-users;

c) **SUBSCRIBER** – the DLS-user can receive, and request, DLSDUs from the associated publishing DLS-user, and can send DLSDUs to that publishing DLS-user.

4.2.2 QoS – DLCEP data delivery features

Both members of a peer DLC, or the publishing DLS-user of a multi-peer DLC, specify the data delivery features of the DLC's DLCEP(s). The five choices for DLCEP data delivery features, and their effects, are

a) **CLASSICAL** – the DLS-user can send data which will be delivered without loss, duplication or misordering. All relevant DLS-users will be notified of any loss of synchronization on the DLC.

b) **DISORDERED** – the DLS-user can send data which will be delivered immediately upon receipt, without duplication but potentially in a different order than that of the sending DLS-user. All relevant DLS-users will be notified of any unrecoverable loss of DLS-user data or loss of synchronization on the DLC.

c) **ORDERED** – the DLS-user can send data which will be delivered immediately upon receipt, without duplication or misordering, but with potential loss of some DLS-user data. Loss of DLS-user data will not be reported, and recovery of DLS-user data lost prior to the last-reported DLS-user data will not be attempted.

d) **UNORDERED** – the DLS-user can send data which will be delivered immediately upon receipt. Loss, duplication and misordering of DLS-user data will not be detected or reported. No attempt will be made by the DLS-provider to recover from such events.

e) **NONE** – the DLS-user cannot send data in this direction of data transfer.

On a peer DLC, the QoS value for the sending DLCEP data delivery features may be chosen independently for each direction of data transfer. On a multi-peer DLC, the QoS value for the DLCEP data delivery features for the subscribers-to-publisher direction of data transfer is restricted to UNORDERED and NONE. The default QoS value for the DLCEP data delivery features in the publisher-to-subscribers direction is UNORDERED.

4.2.3 QoS – DLL priority

All DLCEP establishment requests and responses, all connectionless data transfer requests, and many DL-scheduling requests, specify an associated DLL priority used in scheduling DLL data transfer services. This DLL priority also determines the maximum amount of DLS-user data that can be conveyed in a single DLPDU. The three DLL priorities with their corresponding ranges of conveyable DLS-user data (per DLPDU) are, from highest priority to lowest priority:

a) **URGENT** – ≤ 64 DLS-user octets per DLPDU;

b) **NORMAL** – ≤ 128 DLS-user octets per DLPDU;

c) **TIME-AVAILABLE** – ≤ 256 DLS-user octets per DLPDU.

NOTE 1 URGENT and NORMAL are considered **time-critical** priority levels; TIME-AVAILABLE is considered a **non-time-critical** priority level.

NOTE 2 DLC establishment and DLC release DLPDUs which are sent at TIME-AVAILABLE priority are restricted to convey no more DLS-user data than would be permitted at NORMAL priority – 128 octets.

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4.2.4 QoS – DLPDU authentication

Each DLCEP establishment negotiation, and each connectionless data transfer, uses this attribute to determine

a) a lower bound on the amount of DL-addressing information used in the DLPDUs that provide the associated DLL data transfer services;

NOTE This has a slight impact on the residual rate of DLPDU misdelivery; more addressing information reduces the potential for misdelivery.

b) whether the current state of a sending peer or publisher DLCEP should be sent at low-frequency to the DLC's peer or subscriber DLCEP(s) even when there are no unconfirmed DLS-user requests outstanding at the sending DLCEP;

NOTE This continuing background transmission is known as **residual activity**.

c) whether all related scheduling actions should be executed locally.

NOTE These last two aspects are of particular importance in safety systems.

The three levels specifiable, with their amounts of DL-addressing information, are

1) **ORDINARY** – each DLPDU shall include the minimum amount of addressing information necessary;
2) **SOURCE –** each DLPDU shall include a source DL-address where possible;
3) **MAXIMAL** – each DL-address shall include the maximal amount of addressing information possible. Also, all related scheduling actions should be executed locally; and each sending peer or publisher DLCEP of the DLC should maintain a low-frequency report of state information when there is no DLS-user activity.

4.2.5 QoS – DLL maximum confirm delay

Each DLCEP establishment request, and each response, specifies upper bounds on the maximum time duration permitted for the completion

a) of a DL-CONNECT, DL-RESET or DL-SUBSCRIBER-QUERY primitive, and, separately;
b) of a DL-DATA primitive.

Each connectionless service request specifies an upper bound on the maximum time duration permitted for the completion

c) of a locally-confirmed DL-UNITDATA primitive, and, separately;
d) of a remotely confirmed DL-UNITDATA primitive, a DL-LISTENER-QUERY primitive, or an instance of the DL-UNITDATA-EXCHANGE service.

Each parameter either has the value UNLIMITED or specifies an interval, in units of 1 ms, from 1 ms to 60 s, inclusive. The value UNLIMITED provides compatibility with prior OSI protocols, and provides a means for DL-CONNECT requests to remain in a "listening" or "half-open" state. The completion status of "timeout" cannot occur on a DLS-user request which specifies UNLIMITED.

The parameters for the DL-DATA and locally-confirmed DL-UNITDATA primitives specify intervals less than or equal to that for the DL-CONNECT, DL-RESET, DL-SUBSCRIBER-QUERY, remotely-confirmed DL-UNITDATA, and DL-LISTENER-QUERY primitives.

The intervals specified are the maximum permissible delays

- between the issuing of the specified request primitives and the issuing of the corresponding confirm primitives;
- between the initiation and completion of a single instance of the specified publishing or unitdata-exchange service.

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NOTE For DLEs that do not support a time resolution of 1 ms, the requested time interval may be rounded up to the next-greatest multiple of that resolution that the DLE does support, or to approximately 60 s if the DLE has no sense of time.

Failure to complete a DL-CONNECT or DL-RESET request within the specified interval shall result in a DLS-provider initiated release of the DLCEP, and possibly of the DLC.

4.2.6 QoS – DL-scheduling-policy

For each DLSAP-address, and each DLCEP, the DLS-user can override the normal (implicitly-scheduled) DLL policy of providing the requested DL-service as soon as possible, and instead can defer any inter-DLS-user communication required by a DL-DATA or DL-UNITDATA request DLS-primitive until that deferral is released by an involved DLS-user. Each such release, by execution of a DL-COMPEL-SERVICE request, specifying the DLSAP-address or DLCEP, permits the completion of just a single deferred request DLS-primitive. Only DL-services that provide DLS-user intercommunication are affected by this attribute.

The two choices are

a) **IMPLICIT** – any required communications with peer DLS-user(s) from this DLSAP-address, or from this DLCEP, will occur as soon as possible;

b) **EXPLICIT** – any required data or unitdata communications with peer DLS-user(s) from this DLSAP-address, or from this DLCEP, will occur only when the deferral is explicitly released by an involved DLS-user.

NOTE Scheduling of DLPDU transmission to support the DL-CONNECT, DL-RESET and DL-DISCONNECT services, and to support responder-deferred replies in the DL-UNITDATA-EXCHANGE and remotely-confirmed DL-UNITDATA services, is always IMPLICIT. Scheduling of DLPDU transmission to initiate the DL-UNITDATA-EXCHANGE service is always EXPLICIT.

4.2.7 QoS – maximum DLSDU sizes

Each DLC / DLCEP establishment request, and each response, specifies an upper bound on the size (in octets) of DLSDUs which will be offered for transmission, and an upper bound on the size of DLSDUs which are acceptable for reception.

For peer DLCs, the negotiated maximum DLSDU size shall be determined independently for each direction of data transfer as the smallest of that offered by the sender, that permitted by the sender's local DL-management, that permitted by the receiver's local DL-management, and that permitted by the receiver.

The sender's offered size may be any value between zero and 16 times the maximum number of DLS-user octets per DLPDU, as specified in 4.2.3. The receiving DLE and all DL-management agents shall choose their maximum permitted sizes from the following list of sizes:
0, 64, 128, 256 $\times$ N where $1 \leq N \leq 16$.

NOTE 1 The maximum size DLSDU supported by this protocol is 16 times the maximum number of octets of DLS-user data conveyable in a single DLPDU, as determined by the DLC's DLL Priority (see 4.2.3).

NOTE 2 The set of maximum permitted DLSDU sizes is limited to the above small list of values to promote interoperation. The sender's maximum specified size is permitted to take any value within the range permitted by the DLC's DLL priority to facilitate optimization of the shared communications capacity of the DLL.

NOTE 3 A value of zero (0) corresponds to the choice of simplex service, as specified by the DLS-user by the choice NONE as described in 4.2.2e).

For multi-peer DLCs, the negotiated maximum DLSDU size shall be the smaller of that offered by the publisher and that permitted by the publisher's local DL-management. For subscribers of multi-peer DLCs, the DLC shall be refused by the DLS-provider (the subscriber's DLE) if the maximum DLSDU size established by the publisher is larger than the smaller of that permitted by the subscriber and that permitted by the subscriber's local DL-management.

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The publisher's offered size in the publisher-to-subscribers direction may be any value between zero and 16 times the maximum number of DLS-user octets per DLPDU, as specified in 4.2.3. The publisher's offered size in the subscriber-to-publisher direction may be any value between zero and the maximum number of DLS-user octets per DLPDU, as specified in 4.2.3.

The subscribers and all DL-management agents shall choose their maximum permitted sizes from the following list of sizes: 0, 64, 128, 256 × N where $1 \leq N \leq 16$.

NOTE 4 The maximum size DLSDU supported by this protocol in the publisher-to-subscribers direction is 16 times the maximum number of octets of DLS-user data conveyable in a single DLPDU, as determined by the DLC's DLL Priority (see 4.2.3).

NOTE 5 The maximum size DLSDU supported by this protocol in the subscriber-to-publisher direction is the maximum number of octets of DLS-user data conveyable in a single DLPDU, as determined by the DLC's DLL Priority (see 4.2.3).

NOTE 6 The set of maximum permitted DLSDU sizes is limited to the above small list of values to promote interoperation. The publisher's maximum specified DLSDU size is permitted to take any value within the range permitted by the DLC's DLL priority to facilitate optimization of the shared communications capacity of the DLL.

NOTE 7 A value of zero (0) corresponds to the choice of simplex service, as specified by the DLS-user by the choice NONE as described in 4.2.2e).

The default value for both the sender's and receiver's maximum DLSDU size is the maximum number of DLS-user octets which can be carried by a single DLPDU of the specified DLL priority. The DLS-provider shall always support this DLSDU size.

4.2.8 QoS – DLCEP and DLSAP-address buffer-and-queue bindings

Each DLCEP establishment request, and each response, can bind one or two local retentive buffers or specified-depth FIFO queues, created by DL-CREATE buffer and queue management primitives (or by DL-management), to the DLCEP:

NOTE When these bindings are made for a DLS-user of a peer DLC, or a publishing DLS-user of a multi-peer DLC, they determine the maximum transmit window (that is, number of transmitted but unacknowledged DLSDUs) for that direction of DLC data transfer. Since the size of the transmit window can also be limited by DL-management, or by an implementation, the queue depth only imposes an upper limit on the window size.

a) One queue or retentive buffer can be bound to a DLCEP to convey DLSDUs from the DLS-user to the DLS-provider.

b) One queue or retentive buffer can be bound to a DLCEP to convey DLSDUs from the DLS-provider to the DLS-user.

c) It is also possible to bind a queue or retentive buffer to be written at one DLCEP and to source data at another DLCEP. Such an intermediate buffer or queue can serve to cross scheduling boundaries or redistribute received DLS-user data to a second set of DLS-users.

Such a binding is made by specifying, for the appropriate parameter, a buffer-or-queue DL-identifier which resulted from a prior DL-CREATE request (or by DL-management), and which has not yet been deleted.

When the sending DLCEP data delivery features specify UNORDERED or ORDERED, both the sender and receiver(s) may specify a queuing policy of BUFFER-R or QUEUE. When the DLCEP's sending data delivery features specify DISORDERED or CLASSICAL, both the sender and receiver(s) may specify a queuing policy of QUEUE; a queuing policy of BUFFER-R is not permitted. A queuing policy of BUFFER-NR is never permitted.

Each DLSAP-address bind request can bind up to six local retentive buffers or non-retentive buffers or specified-depth FIFO queues, created by DL-CREATE buffer and queue management primitives (or by DL-management), to the DLSAP-address:

d) One buffer or queue can be bound to the sending direction of a DLSAP-address at each priority to convey DLSDUs from the DLS-user to the DLS-provider. Buffers can be bound

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only to DLSAP-addresses whose DLSAP-role is INITIATOR or CONSTRAINED RESPONDER or UNCONSTRAINED RESPONDER. Queues can be bound only to DLSAP-addresses whose DLSAP-role is BASIC.

e) One buffer or queue can be bound to the receiving direction of a DLSAP-address at each priority to convey DLSDUs from the DLS-provider to the DLS-user. Buffers can be bound only to DLSAP-addresses whose DLSAP-role is INITIATOR or CONSTRAINED RESPONDER or UNCONSTRAINED RESPONDER. Queues can be bound to all DLSAP-addresses.

4.2.8.1 Binding to a buffer

When a sending buffer is bound to a DLCEP, or to a DLSAP-address and DLL priority, by a DLS-user,

a) a DL-PUT request primitive overwrites the buffer with a DLSDU, or may set the buffer empty;

NOTE After creation, the buffer is empty.

b) a DL-COMPEL request primitive, specifying either

1) a DLCEP, or

2) unitdata-exchange at a DLSAP-address

causes the transmission, at the first opportunity, of the then most recent contents of the buffer; the primitive does not itself specify a DLSDU;

c) a DL-BUFFER-SENT indication primitive notifies the DLS-user of the specific DLCEP on which the retentive buffer was transmitted, and to which the buffer is bound, that the buffer was just transmitted;

d) a DL-UNITDATA-EXCHANGE indication primitive notifies the single DLS-user attached to the specific DLSAP-address from which the buffer was transmitted (and to which the buffer is bound) that the buffer was just transmitted on that DLSAP-address, and emptied if it is non-retentive (BUFFER-NR).

When a receiving buffer is bound to a DLCEP, or to a DLSAP-address and DLL priority, by a DLS-user,

e) a DL-BUFFER-RECEIVED or DL-UNITDATA-EXCHANGE indication primitive notifies the DLS-user of the overwriting of the buffer by a newly-received DLSDU; the primitive does not itself specify a DLSDU;

f) a DL-GET request primitive copies the DLSDU from the buffer, and empties the buffer if it is non-retentive (BUFFER-NR).

Multiple concurrent output bindings to a retentive buffer are permitted as an implementation and conformance (see 10.6.1) option, but are not required by this protocol.

4.2.8.2 Binding to a FIFO queue

When a sending FIFO queue of maximum depth *K* is bound to a DLCEP, or to a DLSAP-address and DLL priority, by a DLS-user,

a) a DL-PUT request primitive is not permitted;

b) a DL-DATA or DL-UNITDATA request primitive attempts to append a DLSDU to the queue, but fails if the queue already contains *K* DLSDUs. If the append operation was successful, then the DLSDU will be transmitted at the first opportunity, after all preceding DLSDUs in the queue.

When a receiving FIFO queue of maximum depth *K* is bound to a DLCEP, or to a DLSAP-address and DLL priority, by a DLS-user,

c) a DL-GET request primitive attempts to remove a DLSDU from the queue, but fails if the queue is empty.

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d) a DL-DATA or DL-UNITDATA or DL-UNITDATA-EXCHANGE indication primitive notifies the receiving DLS-user of the result of appending a newly received DLSDU to the receive queue; the primitive does not itself specify a DLSDU.

Multiple concurrent input bindings to a FIFO queue are permitted as an implementation option, but are not required by this protocol.

4.2.8.3 Default bindings

When these binding options are not specified, or for DLS-primitives for which explicit binding is not applicable, the conventional implicitly-queued sending and direct receiving interfaces between DLS-user and DLS-provider are employed. In this case each DL-DATA and DL-UNITDATA primitive conveys a DLSDU, and each DL-CONNECT, DL-DISCONNECT and DL-RESET primitive may convey a DLSDU:

a) DL-PUT and DL-GET request primitives are not permitted;

b) A DL-DATA or DL-UNITDATA or DL-DISCONNECT request primitive, or a DL-CONNECT or DL-RESET request or response primitive, issued by the sending DLS-user attempts to append a DLSDU to the implicit queue, but fails if the queue is full. If the append operation was successful, then the DLSDU will be transmitted at the first opportunity, after all preceding DLSDUs in the queue.

c) A DL-DATA or DL-UNITDATA or DL-DISCONNECT indication primitive, or a DL-CONNECT or DL-RESET indication or confirm primitive, notifies a receiving DLS-user of a newly received DLSDU, and conveys that DLSDU to the DLS-user. No apparent queuing is provided within the DLL.

4.2.9 DL-timeliness

This attribute applies only to DL-buffers, to DLCEPs at which DL-buffers are bound, and to those DLS-primitives which transfer DLS-user data to or from DL-buffers at such DLCEPs.

Each DLCEP establishment request, and each response, can specify DL-timeliness criteria which are to apply to information sent from, or received into, buffers at that DLCEP. Four types of DL-timeliness can be supported: RESIDENCE timeliness, UPDATE timeliness, SYNCHRONIZED timeliness, and TRANSPARENT timeliness. All four types of timeliness, and the case where there is no timeliness, are shown in IEC 61158-3-1, Figure 6.

a) *RESIDENCE* timeliness is an assessment based upon the length of time that a DLS-user datum has been resident in a buffer, which is the time interval between

   1) the moment when the buffer is written (by a DL-PUT request primitive, or by reception into the buffer at a DLCEP);

   2) the moment when the buffer is read (by a DL-GET request primitive, or by transmission from the buffer at a DLCEP);

$$\text{DL-timeliness} \equiv 0 \leq (R_T - W_T) < \Delta T \qquad (1)$$

NOTE This type of timeliness is also known as "*Asynchronous*".

b) *UPDATE* timeliness is an assessment based upon the time interval between

   1) the moment of occurrence of a multi-DLE synchronizing event (a DL-BUFFER-RECEIVED indication or DL-BUFFER-SENT indication);

   2) the moment when the buffer is written (by a DL-PUT request primitive, or by reception into the buffer at a DLCEP);

$$\text{DL-timeliness} \equiv 0 \leq (WT - ST) < \Delta T \qquad (2)$$

NOTE A type of timeliness closely related to this one is also known as "*Punctual*".

c) *SYNCHRONIZED* timeliness is an assessment based upon the time intervals and timing relationships between

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1) the moment of occurrence of a multi-DLE synchronizing event (a DL-BUFFER-RECEIVED indication or DL-BUFFER-SENT indication);
2) the moment when the buffer is written (by a DL-PUT request primitive, or by reception into the buffer at a DLCEP);
3) the moment when the buffer is read (by a DL-GET request primitive, or by transmission from the buffer at a DLCEP);

$$\text{DL-timeliness} \equiv 0 \leq (WT - ST) \leq (RT - ST) < \Delta T \quad (3)$$

NOTE This type of timeliness is also known as "*Synchronous*".

d) *TRANSPARENT* timeliness occurs when timeliness is selected on a DLCEP but none of the above assessments are performed. In such a case the DLC preserves any prior buffer timeliness, but does not itself invalidate that timeliness. When no prior buffer timeliness exists, the default timeliness value shall be TRUE.

e) *NO* timeliness occurs when timeliness is not selected on a DLCEP. In such a case the DL-timeliness attribute of DLS-user data always shall be FALSE.

Where a buffer read or write occurs over a significant time interval, and not just as a momentary event, then the overall timeliness of the read or write operation shall be computed as the timeliness at the beginning of the read or write operation, logically ANDed with the timeliness at the end of the read or write operation, all using the same timeliness criteria.

4.2.10 Remote-DLE-confirmed

Each unitdata transfer request can specify whether confirmation of receipt of the associated DLSDU by the (implicitly addressed) remote DLE is required. Its permissible values are **TRUE** and **FALSE**.

NOTE Selection of the value TRUE inevitably uses more link capacity than does selection of the value FALSE.

4.3 Structure and definition of DL-addresses

DL-addresses are used as DLSAP-addresses and group DL-addresses, as DLCEP-addresses, and as DLSEP-addresses. DL-addresses conform to the following structure and coding limitations.

Clause 4.3 defines the form of DL-addresses and the usage of various ranges of DL-address components. It includes specific definitions for some standard DL-addresses.

This DL-protocol uses individual (non-group) DL-addresses for other purposes than simply as DLSAP-addresses. The same terminology and the following considerations apply to those non-DLSAP DL-addresses as well.

NOTE 1 This usage extends the definition of DL-addresses beyond that specified in ISO/IEC 7498-3.

NOTE 2 DL-addresses are also addressed to some extent in 5.1.

4.3.1 Form of DL-addresses

A standard DL-address may be considered to consist of two parts: link-designator and sublink selector. The link designator is an unsigned integer, two octets in length. The sublink selector is also two octets in length.

Link designator	Sublink selector
2 octets	2 octets

Figure 2 – Basic structure of a DL-address

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Most values of the link designator specify an individual link. In these cases, the sublink selector specifies a unique DL-address within the designated local link, as further described in 4.3.2.2 and 4.3.2.3. When lacking address-specific forwarding information, bridges (relay DLEs) shall base their forwarding decisions only on the link designator portion of such addresses.

However, many values of the link designator specify that the link designator portion of the address is concatenated with the sublink selector portion to form a non-hierarchical (that is, flat) address. When lacking address-specific information, bridges shall not forward such addresses.

A standard sublink selector itself consists of two subparts: node-designator and subnode selector. Each of these subparts is a small unsigned integer, one octet in length.

Implied link designator (0000)	**Node designator**	**Sub-node selector**
	1 octet	1 octet

Figure 3 – Basic structure of a sublink selector

Most values of the node designator specify an individual node. In these cases, the subnode selector specifies a unique DL-address within the designated local node.

However, some values of the node designator specify that the node designator portion of the address is concatenated with the subnode selector portion to form a non-hierarchical (that is, flat) subaddress.

This almost-hierarchical structure of link designators, node designators, and subnode selectors was chosen primarily to facilitate the administration of DL-addresses, and secondarily to reduce the number of entries in bridge address-forwarding tables.

NOTE Protocol implementations may find that this partially hierarchical structure is of use during address recognition.

The resulting structural possibilities for DL-addresses are (where "||" indicates concatenation of the nominal link, node and selector designator subfields):

Link	**Node**	**Selector**
2 octets	1 octet	1 octet

or

Link	**Node || Selector**
2 octets	2 octets

or

Link || Node || Selector
4 octets

Figure 4 – DL-address alternative structures

A DL-address in which the link designator has a value of zero is known as a *local* address because its context for interpretation is limited to the local link. In contrast, other DL-addresses are known as *extended* addresses, because their interpretation context is the entire extended link.

There are four distinct types of DLS-user-visible DL-address:

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a) DLSAP-addresses, which are associated with only one DLSAP in the entire address interpretation context;

b) Group DL-addresses, which are potentially associated with many DLSAPs in one or more DLEs, or with many DLEs;

c) DLCEP-addresses, which are associated

   1) with only one DLCEP and associated DLSAP of a peer-to-peer DLC, or

   2) directly with the publishing DLCEP and associated DLSAP of a multi-peer DLC, and indirectly with all the subscribing DLCEPs and associated DLSAPs of a multi-peer DLC;

d) DLSEP-addresses, which are associated with one sequence-end-point of a single DLE.

DLSAP-addresses may be used with all of the primitives of the DLS which specify a DLSAP-address. Group DL-addresses shall not be

1) bound to a queue as a source DLSAP-address, or

2) used as a source DLSAP-address in any connection-oriented or connectionless DLS primitive.

Individual non-"DLSAP" DL-addresses may be used as appropriate within the DL-protocol, and where permitted as specific parameters within the DL-services.

4.3.2 Predefined values and ranges for DL-address components

Some values of the link-designator or node-designator component of DL-addresses designate a group DL-address. All other combinations of values of the link-designator and node-designator components designate individual DL-addresses. This is summarized in Table 1 through Table 3.

NOTE All link, node and selector values are specified in hexadecimal (radix 16).

4.3.2.1 Link designators

The link designator component of a DL-address usually designates a specific single local link. Values for the link designator component are predefined, or their usage is constrained, as follows:

0000 The local link. The zero (0000) value is provided as a convenience for the unification of service primitives, to enable implementations to refer to the local link's address by a constant zero (0000), and to enable isolated-link operation when no bridge is present to identify the link component of an extended link. When the DLPDU-authentication QoS does not specify *MAXIMAL* and the DL-addresses themselves permit it, the link-designator components of all DL-addresses shall be omitted before transmission. Otherwise, the nominal-link-id of the sourcing local link, if known, shall be substituted for the zero (0000) link value before transmission.

0001 … 003F Non-local group DL-addresses. These link designator values, concatenated with the associated node designator values and selector values – *link* || *node* || *selector* – form an address space of 4 128 768 identifiers usable as group DL-addresses. The resulting DL-addresses do not implicitly designate any specific link.

Non-local group DL-addresses shall be allocated individually or in contiguous blocks. When considered as unsigned 32-bit integers, the first (lowest-valued) eight such addresses are reserved for use by the DL-protocol; the next 56 such addresses are reserved for standardized group DL-addresses. All of the other addresses are available for use as non-standardized group DL-addresses.

0040 … Non-local globally-administered group DL-addresses. These link designator values, concatenated with the associated node designator values and selector values – *link*

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007F *node* || *selector* – form an address space of 4 194 304 identifiers for globally-administered group DL-addresses. These DL-addresses are formed by prefixing the 10-bit string "0000 0000 01" to the lower 22 bits of the Organizationally Unique Identifiers specified in the ISO/IEC 8802 family of Local Area Network standards. These DL-addresses do not implicitly designate any specific link.

Table 1 – Link || node || selector addressing

Link	N | S	Assigned use for specified DL-address range
0000	0000 … FFFF	Local link DL-addresses as specified in Table 2
0001	0000 … 0007	Flat non-local group DL-addresses reserved for DLL use
0001	0008 … 003F	Flat non-local group DL-addresses reserved for standard AEs
0001 … 003F	0040 … FFFF	Flat non-local group DL-addresses available for vendor, user and dynamic assignment
0040 … 007F	0000 … FFFF	Flat non-local globally-administered group DL-addresses – potentially one per vendor (See Note 1)
0080	0000 … 0007	Flat non-local individual "DLSAP"-addresses reserved for DLL use
0080	0008 … 003F	Flat non-local individual DLSAP-addresses reserved for standard AEs
0080 … 00FF	0040 …	Flat non-local individual DLSAP-addresses available for vendor, user and dynamic assignment
0100 … 0FFF	0000 … FFBF	Flat non-local individual DL-addresses available for vendor, user and dynamic assignment as DLCEP-addresses and DLSEP-addresses
0FFF	FFC0 … FFF7	Flat non-local individual DL-addresses reserved for standard AE DLCEP-addresses and DLSEP-addresses
0FFF	FFF8 … FFFF	Flat non-local individual DL-addresses reserved for DLL use as DLCEP-addresses and DLSEP-addresses
1000 … FEFF	0000 … FFFF	Individual links of DL-addresses as specified in Table 2
NOTE These group DL-addresses are based on the Organizationally Unique Identifiers specified in the ISO/IEC 8802 family of Local area network standards.		

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0080 … 00FF — Non-local individual DLSAP-addresses. These link designator values, concatenated with the associated node designator values and selector values – *link* || *node* || *selector* – form an address space of 8 388 608 identifiers usable as individual DLSAP-addresses. The resulting DLSAP-addresses do not implicitly designate any specific link or node.

Non-local individual DLSAP-addresses shall be allocated individually or in contiguous blocks. When considered as unsigned 32-bit integers, the first (lowest-valued) eight such addresses are reserved for use by the DL-protocol as "DLSAP"-addresses; the next 56 such addresses are reserved for standardized individual DLSAP addresses for standard AEs. All of the other addresses are available for use as non-standardized individual DLSAP addresses.

0100 … 0FFF — Non-local individual non-DLSAP DL-addresses usable as DLCEP-addresses and DLSEP-addresses. These link designator values, concatenated with the associated node designator values and selector values – *link* || *node* || *selector* – form an address space of 251 658 240 identifiers usable as individual DLCEP- and DLSEP-addresses. The resulting DL-addresses do not implicitly designate any specific link or node.

Non-local individual non-DLSAP DL-addresses shall be allocated individually or in contiguous blocks. When considered as unsigned 32-bit integers, the last (highest-valued) eight such addresses are reserved for use by the DL-protocol; the next last 56 such addresses are reserved for standardized individual DLCEP-addresses or DLSEP-addresses for standard AEs. All of the other addresses are available for use as non-standardized individual DLCEP addresses and DLSEP-addresses.

1000 … FEFF — Designators of individual links. Link designators shall be allocated, individually or in contiguous blocks, in order of increasing address values when considered as unsigned 16-bit integers.

The value of the DL-management configuration parameter V(ML) shall be greater than or equal to the largest of the link-designator values assigned to links of the extended link.

NOTE This parameter is used by bridges to assist in the provision of default forwarding actions for each link.

NOTE 1 The potential link-designator values FF00 – FFFF are reserved to support the implementation of identifier-references to DL-addresses as noted in IEC 61158-3-1.

In summary, each DLE capable of recognizing LONG DL-addresses (see 5.2.2) recognizes link designator values 0001 – 0FFF as designating the extended group and individual address spaces – *link* || *node* || *selector* – common to the extended link.

Each DLE capable of recognizing LONG DL-addresses recognizes link designator value 0000 as designating the nominal-link, which is a single local link designator value ≥ 1 000. The resulting identifier values – *nominal-link-id* || *node* || *selector* – form an address space of up to 65 280 identifiers usable as individual and group DL-addresses as described in 4.3.2.2.

NOTE 2 The *link* || *node* || *selector* components of these address identifiers take the hexadecimal form WWWWXXYY, where 1000 ≤ WWWW, 01 ≤ XX ≤ FF and 00 ≤ YY ≤ FF. When 01 ≤ XX ≤ 03, such addresses are group DL-addresses; all other such addresses are individual DL-addresses. Addresses where 1 000 ≤ WWWW and XX = 00 refer to the local node, and are valid only within the software of that node.

When the address space needs of a given link exceed that provided by a single nominal-link-id, secondary link-ids may be allocated to that link. For each such secondary link-id, the resulting values – *secondary-link-id* || *node* || *selector* – form an additional address space of

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57 600 identifiers usable as additional individual and group DL-addresses for the link as described in 4.3.2.2.

NOTE 3 The *link* || *node* || *selector* components of these additional address identifiers take the hexadecimal form WWWWXXYY, where 1 000 ≤ WWWW, and either 0140 ≤ XXYY ≤ 03FF, or 0440 ≤ XXYY ≤ 0FBF, or 10 ≤ XX ≤ FF and 08 ≤ YY ≤ F7. When 01 ≤ XX ≤ 03, such address are group DL-addresses; all other such addresses are individual DL-addresses.

DLEs which are not capable of recognizing LONG DL-addresses recognize only SHORT and VERY-SHORT addresses (see 5.2.2), which always designate the nominal-link. Such DLEs are not capable of directly communicating or being directly managed through a bridge.

4.3.2.2 Node designators

The node designator component of a DL-address usually designates a single DLE. When the link designator component does not have the value 0001 – 0FFF, then the values for the node designator component are predefined, or their usage is constrained, as follows:

Table 2 – Link-local node || selector addressing

N	S	Assigned use for specified DL-address range
00	00 … FF	Local node DL-addresses as specified in Table 4
01	00 … 07	Flat link-local group DL-addresses reserved for DLL use
01	08 … 3F	Flat link-local group DL-addresses reserved for standard AEs
01 … 03	40 … FF	Flat link-local group DL-addresses available for vendor, user and dynamic assignment
04	00 … 07	Flat link-local individual “DLSAP”-addresses reserved for DLL use
04	08 … 3F	Flat link-local individual DLSAP-addresses reserved for standard AEs
04	40 … FF	Flat link-local individual DLSAP-addresses available for vendor, user and dynamic assignment
05 … 0F	00 … BF	Flat link-local individual DL-addresses available for vendor, user and dynamic assignment as DLCEP-addresses and DLSEP-addresses
0F	C0 … F7	Flat link-local individual DL-addresses reserved for standard AE DLCEP-addresses and DLSEP-addresses
0F	F8 … FF	Flat link-local individual DL-addresses reserved for DLL use as DLCEP-addresses and DLSEP-addresses
10 … FF	00 … FF	Individual nodes of DL-addresses as specified in Table 4

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00 The local DLE. Equivalent to a DLE-internal address. This designator is provided as a convenience for the unification of service primitives, and to enable implementations to refer to the local DLE address by a constant zero (00). When transmission is appropriate, an implementation shall substitute the DLE's own nominal-node-id for this zero (00) address.

NOTE 1 As a consequence, DLPDUs with a node designator component of zero (00) in a DL-address (other than a flat DL-address) are never transmitted, and are discarded upon reception.

This node designator shall not be used with secondary-link-ids.

01 … 03 Link-local group DL-addresses. These node designator values, concatenated with the nominal or a secondary link-id of the local link and the associated selector values — *link-id* || *node* || *selector* – form address spaces of 768 identifiers each, usable as group DL-addresses.

Link-local group DL-addresses shall be allocated, individually or in contiguous blocks, in order of increasing address values when considered as unsigned 16-bit integers. The first (lowest-valued) such addresses are reserved for use by the DL-protocol; the next 56 such addresses are reserved for standardized group DL-addresses. All of the other addresses are available for use as non-standardized group DL-addresses

04 Link-local individual DLSAP-addresses. These node designator values, concatenated with the nominal or a secondary link-id of the local link and the associated selector values – *link-id* || *node* || *selector* – form address spaces of 256 identifiers each, usable as individual DLSAP-addresses. The resulting DLSAP-addresses do not implicitly designate any specific node.

Link-local individual DLSAP-addresses shall be allocated, individually or in contiguous blocks, in order of increasing address values when considered as unsigned 16-bit integers. The first (lowest-valued) such addresses are reserved for use by the DL-protocol as "DLSAP"-addresses; the next 56 such addresses are reserved for standardized individual DLSAP addresses for standard AEs.

05 … 0F Link-local individual non-DLSAP DL-addresses usable as DLCEP-addresses and DLSEP-addresses. These node designator values, concatenated with the nominal or a secondary link-id of the local link and the associated selector values – *link-id* || *node* || *selector* – form address spaces of 2 816 identifiers usable as individual DLCEP- and DLSEP-addresses. The resulting DL-addresses do not implicitly designate any specific node.

Link-local individual non-DLSAP DL-addresses usable with connected DL-services shall be allocated, individually or in contiguous blocks, in order of decreasing address values when considered as unsigned 16-bit integers. The first (highest-valued) eight such addresses are reserved for use by the DL-protocol; the next 56 such addresses are reserved for standardized individual DLCEP-addresses or DLSEP-addresses for standard AEs. All of the other addresses are available for use as non-standardized individual DLCEP addresses and DLSEP-addresses.

10 … FF Designators of individual nodes. These node designator values, concatenated with the nominal link-id of the local link, provide the equivalent of a "unique hardware address" for each individual physical DLE. Node designators shall be allocated, individually or in contiguous blocks, as shown in Table 3.

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Table 3 – Link-local node designators

N	Assigned use for specified node designator range
00	local DLE
01 … 0F	unusable
10 … 13	Bridge-class DLEs
14	Link-master-class DLEs
15 … F6	unused
F7	Basic-class DLEs
F8 … FB	Non-”visitor” DLEs awaiting proper node designator assignment
FC … FF	“Visitor” DLEs

00 The local DLE. Equivalent to a DLE-internal address. This designator is provided as a convenience for the unification of service primitives, and to enable implementations to refer to the local DLE address by a constant zero (00). When transmission is appropriate, an implementation shall substitute the DLE’s own nominal-node-id for this zero (00) address.

NOTE 2 As a consequence, DLPDUs with a node designator component of zero (00) in a DL-address (other than a flat DL-address) are never transmitted, and are discarded upon reception.

01 … 0F Reserved for unrelated use within the DL-protocol - not available for DLE NODE DL-addresses.

10 … 13 Reserved for allocation to DLEs which bridge (interconnect) the local link (whose link-id is the nominal link-id) to other links, and in particular to higher-capacity links.

NOTE 3 Such bridges are expected to serve as link-local managers for the DL-protocol.

14 Reserved for allocation to other DLEs which are capable of initializing and managing the local link, and which are intended to be permanently attached to the local link (not, for example, maintenance DLEs such as “hand-held communicators”).

These node designators shall be allocated, individually or in contiguous blocks, in order of increasing address values when considered as unsigned 8-bit integers.

15 … F6 Reserved for allocation to DLEs which require more local DL-addresses than are provided hierarchically by the DLE’s primary node designator.

F7 Reserved for allocation to DLEs which are not capable (or are configured to be incapable) of initializing the local link.

These node designators shall be allocated, individually or in contiguous blocks, in order of decreasing address values when considered as unsigned 8-bit integers.

F8 … FB Reserved for temporary use by other DLEs which are intended to be permanently attached to the local link while they determine their appropriate final node designator.

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FC … FF Reserved for allocation to DLEs which are not intended to be permanently attached to the local link (for example, maintenance DLEs such as “hand-held communicators).

NOTE 4 Such “visitor” DLEs normally are capable of initializing and managing the local link, but are the least desirable such DLEs for this purpose since their long-term presence on the link is not expected.

When not used to designate a single DLE, node designator values between those used for DLEs capable of initializing the local link, and those which are incapable (or are configured to be incapable) of initializing the local link, can be concatenated with the nominal or a secondary link-id of the local link, and with selector components whose value is ≥ 08 and ≤ F7, to form additional identifier spaces of 240 individual DL-addresses each – *link-id* || *node* || *selector*. Each such additional address space may be assigned to a single node, or may be shared among the nodes of the link.

NOTE 5 The *node* || *selector* components of these additional address identifiers take the hexadecimal form XXYY, where 10 < XX < FC and 08 ≤ YY ≤ F7.

In summary, when the link designator value designates the local link, then each DLE recognizes node designator values 01 – 0F as designating link-local group and individual address spaces – *link-id* || *node* || *selector* – common to all nodes on the local link.

Each DLE recognizes node designator value 00 as designating a single local node designator value ≥ 10 (hexadecimal), the nominal-node. The resulting identifier values – *nominal-link-id* || *nominal-node-id* || *selector* – form a space of identifiers usable as individual DL-addresses as described in 4.3.2.3.

When the address space needs of a given node exceed that provided by a single nominal-node-id, secondary node-ids may be allocated to that node. For each such secondary node id, the resulting values – *link-id* || *secondary-node-id* || *selector* – with selector component values ≥ 08 and ≤ F7, form an additional space of 240 identifiers usable as additional individual DL-addresses for the node as described in 4.3.2.3. The same method may be used to extend the set of non-node specific individual addresses for the link.

4.3.2.3 Selectors

The selector component of a DL-address usually designates a single protocol entity within the DLE.

When the link designator component does not have the value 0001 – 0FFF, and when the node designator component does not have the value 01 – 0F, then the values for the selector component are predefined, and their usage is constrained, as specified in Table 4.

Table 4 – Node-local selector addressing

Selector	Assigned use for specified DL-address range
00 … 01	Node-local individual “DLSAP”-addresses reserved for DLL use
02 … 07	Node-local individual DLSAP-addresses reserved for standard AEs
08 … 1F	Node-local individual DLSAP-addresses available for vendor, user and dynamic assignment
20 … F7	Node-local individual DL-addresses available for vendor, user and dynamic assignment as DLCEP-addresses and DLSEP-addresses
F8 … FF	Node-local individual DL-addresses reserved for use as standard AE DLCEP-addresses and DLSEP-addresses

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00 … 07 Reserved for standard node-related DLSAP-addresses, and for intra-DLE "DLSAP"-addresses.

08 … 1F Non-standardized individual DLSAP-addresses.

20 … F7 Non-standardized DLCEP-addresses and DLSEP-addresses.

F8 … FF Reserved for standard node-related DLCEP-addresses and DLSEP-addresses.

4.3.3 Predefined DL-addresses

As indicated in Table 1 through Table 3, some specific DL-addresses are defined in Clause 4.3.3. These DL-addresses are defined to facilitate provision of DL-services and initialization of OSI communications within a physically distributed real system.

4.3.3.1 Predefined flat non-local DL-addresses

A number of flat non-local DL-addresses are defined within this subclause, as specified in Table 5.

NOTE SLAE is the System Load Application Entity; SMAE is the System Management Application Entity.

Table 5 – Predefined flat non-local DL-addresses

Link || N || S		Assigned use for specified DL-address
0001	0000	The DL-support functions of "all" (see NOTE) DLEs on the extended link
0001	0001	The DL-support functions of "all" (see NOTE) LM DLEs on the extended link
0001	0002	The DL-support functions of "all" (see NOTE) bridge DLEs on the extended link
0001	0003	The DL-bridge functions of "all" (see NOTE) bridge DLEs on the extended link
0001	0008	The SMAEs of "all" (see NOTE) unconfigured DLEs on the extended link
0001	0009	The SMAEs of "all" (see NOTE) DLEs on the extended link
0001	000A	The SMAEs of "all" (see NOTE) LM DLEs on the extended link
0001	000B	The SMAEs of "all" (see NOTE) bridge DLEs on the extended link
0001	000C	The SLAEs of "all" (see NOTE) LoadServers on the extended link
0001	000D	The SLAEs of "all" (see NOTE) LoadableDevices on the extended link
0080	0000	Reserved for DLL use for a DL-support "DLSAP"-address (See NOTE)
0080	0004	The "DLSAP"-address for the DL-bridge functions of the bridge DLE on the extended link which is the root bridge of the spanning tree
0FFF	FFFE	The DLCEP-address for the DLC from the bridge functions of the bridge DLE on the extended link which is the root bridge of the spanning tree to the bridge functions in all other bridge DLEs on the extended link
0FFF	FFFF	Reserved for DLL use for a DL-support DLCEP-address or DLSEP-address (See NOTE)

NOTE DLEs which do not recognize LONG DL-addresses are necessarily excluded from these sets.

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4.3.3.2 Predefined flat local DL-addresses

A number of flat local DL-addresses are defined within this subclause, as specified in Table 6. These correspond one-for-one with the predefined flat non-local DL-addresses specified in Table 5. The extent of the addresses in Table 6 is the local link; the extent of the addresses in Table 5 is the entire extended link.

The DL-addresses in Table 6 have a one-for-one correspondence with analogous DL-addresses in Table 5; while the addresses in Table 6 refer to functions local to each link, the analogous addresses of Table 5 refer to similar functions global to the entire extended link. This addressing correspondence is intentional, and may serve to ease implementation complexity. Thus this correspondence should be preserved in future address assignments.

Table 6 – Predefined flat link-local DL-addresses

Node || selector		Assigned use for specified DL-address
01	00	The DL-support functions of all DLEs on the link
01	01	The DL-support functions of all LM DLEs on the link
01	02	The DL-support functions of all bridge DLEs on the link
01	03	The DL-bridge functions of all bridge DLEs on the link
01	08	The SMAEs of all unconfigured DLEs on the link
01	09	The SMAEs of all DLEs on the link
01	0A	The SMAEs of all LM DLEs on the link
01	0B	The SMAEs of all bridge DLEs on the link
01	0C	The SLAEs of all LoadServers on the link
01	0D	The SLAEs of all LoadableDevices on the link
04	00	The “DLSAP”-address for the DL-support functions of the DLE on the link which is serving as LAS
04	04	The “DLSAP”-address for the DL-bridge functions of the bridge DLE on the link which is dominant (closest to the root) in the bridge spanning tree
0F	FE	The DLCEP-address for the DLC from the bridge functions of the bridge DLE on the link which is dominant (closest to the root) in the bridge spanning tree to the bridge functions in all other bridge DLEs on the link
0F	FF	The DLCEP-address for the DLC from the DL-support functions of the DLE on the link which is serving as LAS to the DL-support functions of all of the other LM DLEs on the link

4.3.3.3 Predefined node-local DL-addresses

A number of node-local DL-addresses are defined within this subclause, as specified in Table 7.

Table 7 – Predefined node-local DL-addresses

Selector	Assigned use for specified DL-address
00	The “DLSAP”-address for the DL-support functions of the node’s DLE
01	The “DLSAP”-address for the DL-bridge functions of the node’s DLE
02	The DLSAP-address for the node’s same
03	The DLSAP-address for the node’s SLAE

4.3.4 Representation of DL-Addresses as locally-administered 48-bit MAC-addresses

The ISO/IEC Local Area Network protocols (ISO/IEC 8802) provide a foundation for portions of the IEC fieldbus protocols, such as the Ph-redundancy state machine, the inter-DLE data

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