

DIN EN IEC 61158-4-3

ICS 35.100.20; 35.160

Ersatz für
DIN EN 61158-4-3:2015-09
Siehe Anwendungsbeginn

**Industrielle Kommunikationsnetze –
Feldbusse –
Teil 4-3: Protokollspezifikation des Data-Link Layer
(Sicherungsschicht) – Typ 3-Elemente
(IEC 61158-4-3:2019);
Englische Fassung EN IEC 61158-4-3:2019, nur auf CD-ROM**

Industrial communication networks –
Fieldbus specifications –
Part 4-3: Data-link layer protocol specification – Type 3 elements
(IEC 61158-4-3:2019);
English version EN IEC 61158-4-3:2019, only on CD-ROM

Réseaux de communication industriels –
Spécifications des bus de terrain –
Partie 4-3: Spécification du protocole de la couche liaison de données – Éléments de
Type 3
(IEC 61158-4-3:2019);
Version anglaise EN IEC 61158-4-3:2019, seulement en CD-ROM

Gesamtumfang 178 Seiten

DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN und VDE

Anwendungsbeginn

Anwendungsbeginn für die von CENELEC am 2019-05-23 angenommene Europäische Norm als DIN-Norm ist 2020-08-01.

Für DIN EN 61158-4-3:2015-09 besteht eine Übergangsfrist bis 2022-05-23.

Nationales Vorwort

Vorausgegangener Norm-Entwurf: E DIN EN 61158-400:2017-12.

Dieser Entwurf betrifft auch die Normen DIN EN IEC 61158-4-2:2020-08, DIN EN IEC 61158-4-4:2020-08, DIN EN IEC 61158-4-12:2020-08, DIN EN IEC 61158-4-19:2020-08, DIN EN IEC 61158-4-21:2020-08, DIN EN IEC 61158-4-24:2020-08 und DIN EN IEC 61158-4-25:2020-08.

Für dieses Dokument ist das nationale Arbeitsgremium K 956 „Industrielle Kommunikation“ der DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN und VDE (www.dke.de) zuständig.

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- geändert.

Für den Fall einer undatierten Verweisung im normativen Text (Verweisung auf ein Dokument ohne Angabe des Ausgabedatums und ohne Hinweis auf eine Abschnittsnummer, eine Tabelle, ein Bild usw.) bezieht sich die Verweisung auf die jeweils aktuellste Ausgabe des in Bezug genommenen Dokuments.

Für den Fall einer datierten Verweisung im normativen Text bezieht sich die Verweisung immer auf die in Bezug genommene Ausgabe des Dokuments.

Der Zusammenhang der zitierten Dokumente mit den entsprechenden deutschen Dokumenten ergibt sich, soweit ein Zusammenhang besteht, grundsätzlich über die Nummer der entsprechenden IEC-Publikation. Beispiel: IEC 60068 ist als EN 60068 als Europäische Norm durch CENELEC übernommen und als DIN EN 60068 ins Deutsche Normenwerk aufgenommen.

Das Präsidium des DIN hat mit Präsidialbeschluss 1/2004 festgelegt, dass DIN-Normen, deren Inhalt sich auf internationale Arbeitsergebnisse der Informationsverarbeitung gründet, unter bestimmten Bedingungen allein in englischer Sprache veröffentlicht werden dürfen. Diese Bedingungen sind für die vorliegende Norm erfüllt.

Da sich die Benutzer der vorliegenden Norm der englischen Sprache als Fachsprache bedienen, wird die Englische Fassung der EN IEC 61158-4-3 veröffentlicht. Zu deren Abschnitt 1, der den Anwendungsbereich festlegt und Abschnitt 3 (außer Unterabschnitte 3.1, 3.2, 3.5 und 3.6), der die Begriffe festlegt, wurde eine Übersetzung angefertigt und als informativer Nationaler Anhang NA der vorliegenden Norm hinzugefügt. Für die meisten der verwendeten Begriffe existieren keine gebräuchlichen deutschen Benennungen, da sich die deutschen Anwender in der Regel ebenfalls der englischen Benennungen bedienen. Diese Norm steht nicht in unmittelbarem Zusammenhang mit Rechtsvorschriften und ist nicht als Sicherheitsnorm anzusehen.

Das Original-Dokument enthält Bilder in Farbe, die in der Papierversion in einer Graustufen-Darstellung wiedergegeben werden. Elektronische Versionen dieses Dokuments enthalten die Bilder in der originalen Farbdarstellung.

Ein Feldbus ist ein digitaler serieller Datenbus für die Kommunikation zwischen Geräten der industriellen Automatisierungstechnik wie beispielsweise Messeinrichtungen, Stellgliedern, Reglern und speicherprogrammierbaren Steuerungen. Die Normen der Reihe DIN EN IEC 61158 legen eine Anzahl von Feldbus-Protokolltypen fest. Die vorliegende Norm legt das Protokoll des Data-Link Layer für die einzelnen Typen fest.

Änderungen

Gegenüber DIN EN 61158-4-3:2015-09 wurden folgende Änderungen vorgenommen:

- a) Korrektur in Tabelle 3 und Tabelle A.15;
- b) sonstige redaktionelle Änderungen.

Frühere Ausgaben

DIN V 19245-1: 1988-01
DIN 19245-1: 1991-04
DIN 19245-2: 1991-04
DIN EN 50170/1: 1997-07
DIN EN 50170/2: 1997-07
DIN EN 50170/3: 1997-07
DIN EN 50254: 1999-07
DIN EN 50170/A2: 2000-08
DIN EN 50170/A1: 2002-11
DIN EN 50170/A3: 2002-11
DIN EN 61158-4: 2005-05
DIN EN 61158-4-3: 2008-09, 2013-01, 2015-09

Nationaler Anhang NA (informativ)

Auszugsweise Übersetzung

Reihenfolge und Inhalt der folgenden Abschnitte sind identisch mit denen in den jeweiligen Abschnitten der Englischen Fassung.

EINLEITUNG

Dieser Teil von IEC 61158 gehört zu einer Normenreihe, die zur Erleichterung der Verbindung von Komponenten von Automatisierungssystemen erstellt wurde. Es ist mit anderen Normen der Reihe verbunden, wie durch das in IEC 61158-1 beschriebene „dreischichtige“ Feldbus-Referenzmodell definiert.

Das Datenverbindungsprotokoll stellt den Datenverbindungsdienst bereit, indem es die Dienste nutzt, die in der physikalischen Schicht verfügbar sind. Das vorrangige Ziel dieses Dokuments ist es, eine Reihe von Regeln für die Kommunikation zu erstellen, die sich auf die Verfahren beziehen, die von den Peer Data-Link Entities (DLE) zum Zeitpunkt der Kommunikation durchzuführen sind. Diese Regeln für die Kommunikation sollen eine stabile Grundlage für die Weiterentwicklung bilden, damit sie einer Vielzahl von Zwecken dienen können:

- a) als Leitfaden für Implementierer und Konstrukteure;
- b) zur Verwendung bei der Prüfung und Beschaffung von Ausrüstung;
- c) als Teil einer Vereinbarung über die Zulassung von Systemen in der offenen Systemumgebung;
- d) als eine Erweiterung des Verständnisses von zeitkritischer Kommunikation innerhalb der OSI.

Dieses Dokument befasst sich insbesondere mit der Kommunikation und dem Zusammenwirken von Sensoren, Effektoren und anderen Automatisierungsgeräten. Durch die Verwendung dieses Dokuments zusammen mit anderen Normen, die innerhalb der OSI- oder Feldbus-Referenzmodelle vorhanden sind, können andernfalls inkompatible Systeme in beliebiger Kombination zusammenarbeiten.

ANMERKUNG Die Verwendung einiger der zugehörigen Protokolltypen ist durch die Inhaber ihrer geistigen Eigentumsrechte eingeschränkt. In allen Fällen erlaubt die Verpflichtung zur begrenzten Freigabe von Rechten an geistigem Eigentum, die von den Inhabern dieser Rechte eingegangen wurde, die Verwendung eines bestimmten Protokolltyps der Daten Verbindungsschicht mit Protokollen der physikalischen Schicht und der Anwendungsschicht in Typkombinationen, wie sie in den Profileilen ausdrücklich festgelegt sind. Die Verwendung der Protokolltypen in anderen Kombinationen kann die Genehmigung der jeweiligen Inhaber der geistigen Eigentumsrechte erfordern.

1 Anwendungsbereich

1.1 Allgemeines

Der Data-Link Layer stellt grundlegende zeitkritische Messaging-Kommunikationen zwischen Geräten in einem Automatisierungsumfeld bereit.

Dieses Protokoll stellt Kommunikationsmöglichkeiten für eine vorgewählte „Master“-Teilmenge von Data-Link-Instanzen zyklisch asynchron bereit, sequentiell für jede dieser Data-Link-Instanzen. Andere Data-Link-Instanzen kommunizieren nur, wie durch diese „Master“-Data-Link-Instanzen genehmigt und delegiert.

Für einen gegebenen Master können dessen Kommunikationen mit anderen Data-Link-Instanzen zyklisch, azyklisch mit vorrangigem Zugriff oder eine Kombination beider sein.

Dieses Protokoll stellt Mittel für gemeinsame Nutzung der verfügbaren Kommunikationsressourcen auf gerechte Weise bereit. Es gibt Bestimmungen für Zeitsynchronisation und für isochronen Betrieb.

1.2 Spezifikationen

Dieses Dokument legt fest:

- a) Verfahren für den rechtzeitigen Transfer von Daten und Steuerinformationen von einer Data-Link-Benutzerinstanz zu einer Peer-Benutzerinstanz und unter den Data-Link-Instanzen, die den verteilten Data-Link-Dienstanbieter bilden;
- b) die Struktur der Feldbus-DLPDU, die für den Transfer von Daten und Steuerinformationen durch das Protokoll dieses Dokuments verwendet werden, und deren Darstellung als physische Schnittstelleneinheiten.

1.3 Verfahren

Die Verfahren sind definiert hinsichtlich:

- a) der Interaktionen zwischen Peer-DL-Instanzen (DLE, DL-entities) über den Austausch von Feldbus-DLPDU;
- b) der Interaktionen zwischen einem DL-Dienst-(DLS, DL-service)-Anbieter und einem DLS-Benutzer in demselben System über den Austausch von DLS-Primitiven;
- c) der Interaktionen zwischen einem DLS-Anbieter und einem Ph-Dienstanbieter in demselben System über den Austausch von Ph-Dienstprimitiven.

1.4 Anwendbarkeit

Diese Verfahren sind anwendbar auf Kommunikationsvorgänge zwischen Systemen, die zeitkritische Kommunikationsdienste innerhalb des Data-Link Layer des OSI- oder Feldbus-Referenzmodells unterstützen und die die Fähigkeit des Durchverbindens in einem Umfeld der Kommunikation offener Systeme erfordern.

Profile stellen eine einfache multiattributive Einrichtung zum Zusammenfassen des Vermögens einer Implementierung bereit und somit deren Anwendbarkeit auf verschiedene zeitkritische Kommunikationsanforderungen.

1.5 Konformität

Dieses Dokument legt außerdem Konformitätsanforderungen für Systeme fest, die diese Verfahren umsetzen. Dieses Dokument enthält keine Prüfungen zum Darlegen der Erfüllung solcher Anforderungen.

3 Begriffe, Symbole, Abkürzungen und Vereinbarungen

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe, Symbole, Abkürzungen und Vereinbarungen.

ISO und IEC stellen terminologische Datenbanken für die Verwendung in der Normung unter den folgenden Adressen bereit:

- IEC Electropedia: verfügbar unter <http://www.electropedia.org/>
- ISO Online Browsing Platform: verfügbar unter <http://www.iso.org/obp>

3.3 Allgemeine Begriffe

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe.

ANMERKUNG Viele Definitionen treffen auf mehr als einen Protokoll-Typ zu; sie werden nicht zwangsweise von allen Protokoll-Typen verwendet.

3.3.1

DL-Segment

(en: DL-segment)

Verbindungszweig

(en: link)

lokaler Verbindungszweig

(en: local link)

einzelnes DL-Subnetzwerk, in dem alle angeschlossenen DLE direkt, d. h. ohne zwischengeschaltete DL-Weitergabe, kommunizieren dürfen, solange alle diese an einem Kommunikationsvorgang teilnehmenden DLE während der Dauer(n) der Kommunikationsversuche gleichzeitig auf das DL-Subnetzwerk reagieren können

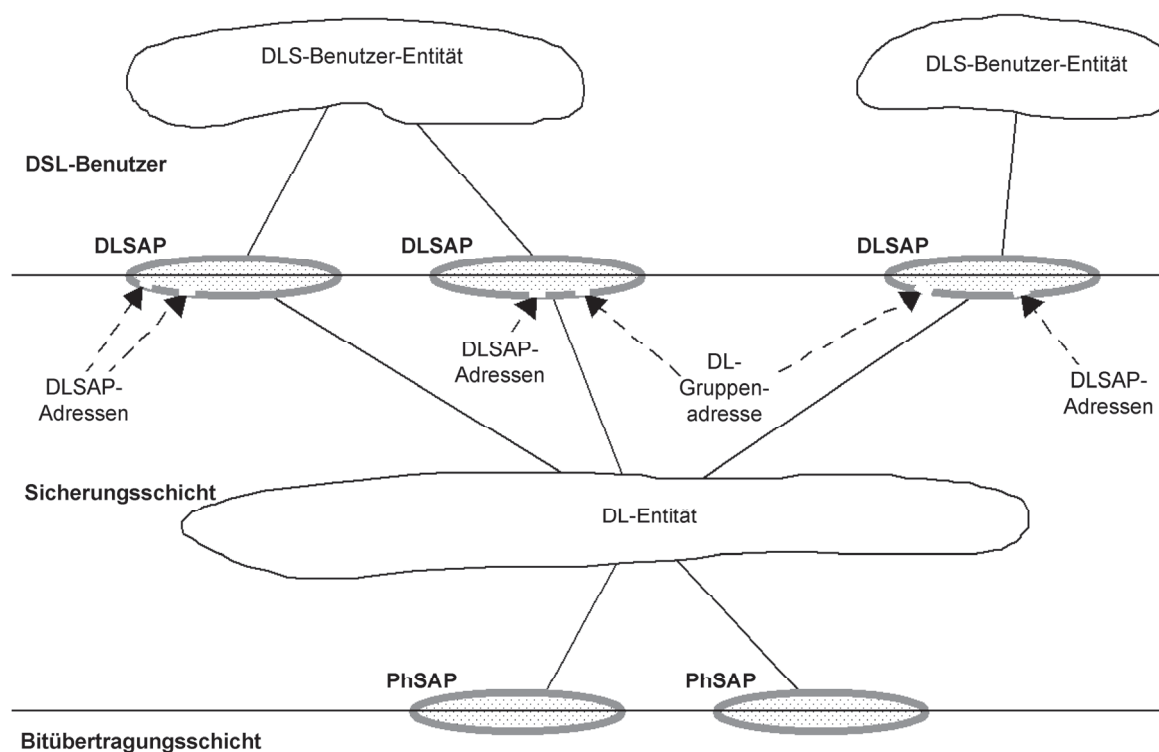
3.3.2

DLSAP

(en: DLSAP)

eindeutiger Punkt, an dem eine einzelne DL-Instanz an eine einzelne Instanz einer höheren Schicht DL-Dienste bereitstellt

Anmerkung 1 zum Begriff: Dieser aus der ISO/IEC 7498-1 abgeleitete Begriff wird hier wiederholt, um das Verständnis für die kritische Unterscheidung zwischen DLSAPs und ihren DL-Adressen zu erleichtern. (Siehe Bild 1.)



ANMERKUNG 1 DLSAPs und PhSAPs werden als Ovale dargestellt, die die Grenze zwischen zwei benachbarten Schichten überbrücken.

ANMERKUNG 2 DL-Adressen werden als Bezeichnung für kleine Lücken (Zugriffspunkte) im DLL-Teil eines DLSAPs dargestellt.

ANMERKUNG 3 Eine einzelne DL-Entität kann mehrere DLSAP-Adressen und Gruppen-DL-Adressen haben, die mit einem einzigen DLSAP verbunden sind.

Bild 1 – Beziehungen von DLSAPs, DLSAP-Adressen und Gruppen-DL-Adressen

3.3.3**DL(SAP)-Adresse**

(en: DL(SAP)-address)

entweder eine individuelle DLSAP-Adresse, die einen einzelnen DLSAP eines einzelnen DLS-Benutzers kennzeichnet, oder eine DL-Gruppenadresse, die möglicherweise mehrere DLSAP, jeweils eines einzelnen DLS-Benutzers, kennzeichnet

Anmerkung 1 zum Begriff: Diese Terminologie wird gewählt, da ISO/IEC 7498-3 die Verwendung des Begriffs „DLSAP-Adresse“ zur Bezeichnung von mehr als einem einzelnen DLSAP bei einem einzelnen DLS-Benutzer nicht zulässt.

3.3.4**(individuelle) DLSAP-Adresse**

(en: (individual) DLSAP-address)

DL-Adresse, die nur einen DLSAP innerhalb des erweiterten Verbindungszweigs kennzeichnet

Anmerkung 1 zum Begriff: Eine einzelne DL-Instanz darf mehrere DLSAP-Adressen, die einem einzelnen DLSAP zugeordnet sind, aufweisen.

3.3.5**erweiterter Verbindungszweig**

(en: extended link)

DL-Subnetzwerk, das aus der maximalen Menge von Verbindungszweigen, die mittels DL-Relais verbunden sind, besteht, wobei ein einzelner DL-Namensraum (DL-Adressraum) gemeinsam genutzt wird, wobei in dem Subnetzwerk alle angeschlossenen DL-Instanzen entweder direkt oder über eine oder mehrere der zwischengeschalteten DL-Relais-Instanzen miteinander kommunizieren dürfen

Anmerkung 1 zum Begriff: Ein erweiterter Verbindungszweig darf aus nur einem einzelnen Verbindungszweig gebildet sein.

3.3.6**Rahmen**

(en: frame)

umgangssprachliches Synonym für DLPDU

3.3.7**DL-Gruppenadresse**

(en: group DL-address)

DL-Adresse, die möglicherweise mehr als einen DLSAP innerhalb des erweiterten Verbindungszweigs kennzeichnet

Anmerkung 1 zum Begriff: Eine einzelne DL-Instanz darf mehrere DL-Gruppenadressen, die einem einzelnen DLSAP zugeordnet sind, aufweisen.

Anmerkung 2 zum Begriff: Eine einzelne DL-Instanz darf auch eine einzelne DL-Gruppenadresse, die mehr als einem DLSAP zugeordnet ist, aufweisen

3.3.8**Knoten**

(en: node)

einzelne DL-Instanz, wie sie auf einem lokalen Verbindungszweig existiert

3.3.9**empfangender DLS-Benutzer**

(en: receiving DLS-user)

Benutzer der DL-Dienste, der als ein Empfänger von DL-Benutzerdaten agiert

Anmerkung 1 zum Begriff: Ein Benutzer der DL-Dienste kann gleichzeitig sendender und empfangender DLS-Benutzer sein.

3.3.10

sendender DLS-Benutzer

(en: sending DLS-user)

Benutzer der DL-Dienste, der als Quelle von DL-Benutzerdaten agiert

3.4 Zusätzliche Typ-3-Definitionen

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe.

3.4.1

Bestätigungs-DLPDU

(en: acknowledge DLPDU)

Rückmeldungs-DLPDU, die keine DLSDU enthält

3.4.2

Adresserweiterung

(en: address extension)

DLSAP-Adresse oder Regions-/Segmentadresse

3.4.3

Bitzeit

(en: bit time)

Dauer für die Übertragung eines Bits

3.4.4

bestätigter Nachrichtenaustausch

(en: confirmed message exchange)

vollständiger Datentransfer mit Anforderungs- und Bestätigungs- oder Antwort-DLPDU

3.4.5

controller_type

(en: controller_type)

Hardware-Klasse der Kommunikationsinstanz

3.4.6

aktueller Master

(en: current master)

Tokenhalter

3.4.7

Daten-DLPDU

(en: data DLPDU)

DLPDU, die eine DLSDU von einem lokalen DLS-Benutzer an einen entfernten DLS-Benutzer überträgt

3.4.8

DL_status

(en: DL_status)

Status, der das Ergebnis der Ausführung der zugehörigen Anforderung festlegt

3.4.9

GAP

(en: GAP)

Bereich von DL-Stationsadressen (DLE-Adressen) zwischen dieser Station (TS) und ihrem Nachfolger (NS) im logischen Tokenring, ausgenommen Stationen über der höchsten Stationsadresse (HSA, en: highest station address)

3.4.10

GAP-Verwaltung

(en: GAP maintenance)

Registrierung neuer Master- und Slave-Stationen

3.4.11**isochroner Modus**

(en: isochronous mode)

spezieller Betriebsmodus, der sowohl einen konstanten (isochronen) Zyklus mit einem festen Plan von Nachrichten hoher und niedriger Priorität als auch die Synchronisation der DLS-Benutzer mit diesem konstanten (isochronen) Zyklus einschließt

3.4.12**lokaler DLS-Benutzer**

(en: local DLS-user)

DLS-Benutzer, der den aktuellen Dienst initiiert

3.4.13**Nachrichtenaustausch**

(en: message exchange)

vollständiger bestätigter oder unbestätigter Datentransfer

3.4.14**Regions-/Segmentadresse**

(en: region/segment address)

Adresserweiterung, die ein bestimmtes Subnetzwerk des Feldbusses bezeichnet

Anmerkung 1 zum Begriff: Dies unterstützt das DL-Routing zwischen Feldbussen.

3.4.15**Anforderungsdaten**

(en: request data)

DLSDU, die der entfernte DLS-Benutzer dem lokalen DLS-Benutzer bereitstellt

3.4.16**entfernte DLE**

(en: remote DLE)

adressierte DLE einer Dienstanforderung (d. h. die vorgesehene empfangende DLE jeder resultierenden Sende-/Anforderungs-DLPDU)

3.4.17**entfernter DLS-Benutzer**

(en: remote DLS-user)

adressierter DLS-Benutzer einer Dienstanforderung (d. h. der vorgesehene Empfänger jedes resultierenden Anzeigeprimitivs)

3.4.18**Rückmeldungs-DLPDU**

(en: reply DLPDU)

DLPDU, die von einer entfernten DLE an die initiiierende (lokale) DLE und möglicherweise andere DLE übertragen wird

Anmerkung 1 zum Begriff: Wenn die entfernte DLE ein Publisher ist, kann die Rückmeldungs-DLPDU auch an mehrere entfernte DLE gesendet werden.

3.4.19**Antwort-DLPDU**

(en: response DLPDU)

Rückmeldungs-DLPDU, die eine DLSDU von einem entfernten DLS-Benutzer an einen lokalen DLS-Benutzer überträgt

3.4.20**Sendedaten**

(en: send data)

DLSDU, die ein lokaler DLS-Benutzer einem entfernten DLS-Benutzer bereitstellt

3.4.21

Sende-/Anforderungs-DLPDU

(en: send/request DLPDU)

DLPDU, die entweder eine Anforderung von Daten oder eine DLSDU oder beides von einem lokalen DLS-Benutzer an einen entfernten DLS-Benutzer überträgt

3.4.22

Zeit-Master

(en: time master)

Gerät, das in der Lage ist, DLPDU zur Uhrensynchronisation zu senden

Anmerkung 1 zum Begriff: Link Devices verfügen über eine Zeit-Master-Funktionalität.

3.4.23

Zeitempfänger

(en: time receiver)

Gerät, dessen Uhrzeit von einem Zeit-Master synchronisiert werden kann

3.4.24

Tokenhalter

(en: token holder)

Master-Station, die den Zugriff auf den Bus steuert

3.4.25

Tokenweitergabe

(en: token passing)

Medienzugriffsverfahren, bei dem das Recht zur Übertragung von einer Master-Station zur nächsten Master-Station in einem logischen Ring weitergegeben wird

English Version

**Industrial communication networks - Fieldbus specifications -
Part 4-3: Data-link layer protocol specification - Type 3 elements
(IEC 61158-4-3:2019)**

Réseaux de communication industriels - Spécifications des
bus de terrain - Partie 4-3: Spécification du protocole de la
couche liaison de données - Éléments de Type 3
(IEC 61158-4-3:2019)

Industrielle Kommunikationsnetze - Feldbusse -
Teil 4-3: Protokollspezifikation des Data-Link Layer
(Sicherheitsschicht) - Typ 3-Elemente
(IEC 61158-4-3:2019)

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

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

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

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

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

European foreword

The text of document 65C/946/FDIS, future edition 4 of IEC 61158-4-3, prepared by SC 65C "Industrial networks" of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61158-4-3:2019.

The following dates are fixed:

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

This document supersedes EN 61158-4-3:2014.

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

Endorsement notice

The text of the International Standard IEC 61158-4-3:2019 was approved by CENELEC as a European Standard without any modification.

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

IEC 60870-5-1	NOTE	Harmonized as EN 60870-5-1.
IEC 61158-1	NOTE	Harmonized as EN 61158-1.
IEC 61158-5-3	NOTE	Harmonized as EN 61158-5-3.
IEC 61158-6-3	NOTE	Harmonized as EN 61158-6-3.
IEC 61784-1	NOTE	Harmonized as EN 61784-1.
IEC 61784-2	NOTE	Harmonized as EN 61784-2.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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

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

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

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61131-3	-	Programmable controllers - Part 3: Programming languages	EN 61131-3	-
IEC 61158-2	2014	Industrial communication networks - Fieldbus specifications - Part 2: Physical layer specification and service definition	EN 61158-2	2014
IEC 61158-3-3	2014	Industrial communication networks - Fieldbus specifications - Part 3-3: Data-link layer service definition - Type 3 elements	EN 61158-3-3	2014
ISO 1177	-	Information processing - Character structure for start/stop and synchronous character oriented transmission		-
ISO/IEC 646	-	Information technology - ISO 7-bit coded-character set for information interchange		-
ISO/IEC 2022	-	Information technology - Character code-structure and extension techniques		-
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 10731	-	Information technology - Open Systems-Interconnection - Basic Reference Model - Conventions for the definition of OSI services		-

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INTRODUCTION

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

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

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

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

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

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-3: Data-link layer protocol specification – Type 3 elements

1 Scope

1.1 General

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

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

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

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

1.2 Specifications

This document 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 document, and their representation as physical interface data units.

1.3 Procedures

The procedures are defined in terms of

- a) the interactions between peer DL-entities (DLEs) through the exchange of fieldbus DLPDUs;
- b) the interactions between a DL-service (DLS) provider and a DLS-user in the same system through the exchange of DLS primitives;
- c) the interactions between a DLS-provider and a Ph-service provider in the same system through the exchange of Ph-service primitives.

1.4 Applicability

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

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

1.5 Conformance

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

2 Normative references

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

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

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

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

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

ISO/IEC 646, *Information technology – ISO 7-bit coded character set for information interchange*

ISO/IEC 2022, *Information technology – Character code structure and extension techniques*

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

ISO 1177, *Information processing – Character structure for start/stop and synchronous character oriented transmission*

3 Terms, definitions, symbols and abbreviations

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

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

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

3.1 Reference model terms and definitions

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

3.1.1	called-DL-address	[ISO/IEC 7498-3]
3.1.2	calling-DL-address	[ISO/IEC 7498-3]
3.1.3	centralized multi-end-point-connection	[ISO/IEC 7498-3]
3.1.4	correspondent (N)-entities correspondent DL-entities (N=2) correspondent Ph-entities (N=1)	[ISO/IEC 7498-3]
3.1.5	demultiplexing	[ISO/IEC 7498-3]
3.1.6	DL-address	[ISO/IEC 7498-3]
3.1.7	DL-address-mapping	[ISO/IEC 7498-3]
3.1.8	DL-connection	[ISO/IEC 7498-3]
3.1.9	DL-connection-end-point	[ISO/IEC 7498-3]
3.1.10	DL-connection-end-point-identifier	[ISO/IEC 7498-3]
3.1.11	DL-connection-mode transmission	[ISO/IEC 7498-3]
3.1.12	DL-connectionless-mode transmission	[ISO/IEC 7498-3]
3.1.13	DL-data-sink	[ISO/IEC 7498-3]
3.1.14	DL-data-source	[ISO/IEC 7498-3]
3.1.15	DL-duplex-transmission	[ISO/IEC 7498-3]
3.1.16	DL-facility	[ISO/IEC 7498-3]
3.1.17	DL-local-view	[ISO/IEC 7498-3]
3.1.18	DL-name	[ISO/IEC 7498-3]
3.1.19	DL-protocol	[ISO/IEC 7498-3]
3.1.20	DL-protocol-connection-identifier	[ISO/IEC 7498-3]
3.1.21	DL-protocol-control-information	[ISO/IEC 7498-3]
3.1.22	DL-protocol-data-unit	[ISO/IEC 7498-3]
3.1.23	DL-protocol-version-identifier	[ISO/IEC 7498-3]
3.1.24	DL-relay	[ISO/IEC 7498-3]
3.1.25	DL-service-connection-identifier	[ISO/IEC 7498-3]
3.1.26	DL-service-data-unit	[ISO/IEC 7498-3]
3.1.27	DL-simplex-transmission	[ISO/IEC 7498-3]
3.1.28	DL-subsystem	[ISO/IEC 7498-3]
3.1.29	DL-user-data	[ISO/IEC 7498-3]
3.1.30	flow control	[ISO/IEC 7498-3]
3.1.31	layer-management	[ISO/IEC 7498-3]

3.1.32	multiplexing	[ISO/IEC 7498-3]
3.1.33	naming-(addressing)-authority	[ISO/IEC 7498-3]
3.1.34	naming-(addressing)-domain	[ISO/IEC 7498-3]
3.1.35	naming-(addressing)-subdomain	[ISO/IEC 7498-3]
3.1.36	(N)-entity DL-entity Ph-entity	[ISO/IEC 7498-3]
3.1.37	(N)-interface-data-unit DL-service-data-unit (N=2) Ph-interface-data-unit (N=1)	[ISO/IEC 7498-3]
3.1.38	(N)-layer DL-layer (N=2) Ph-layer (N=1)	[ISO/IEC 7498-3]
3.1.39	(N)-service DL-service (N=2) Ph-service (N=1)	[ISO/IEC 7498-3]
3.1.40	(N)-service-access-point DL-service-access-point (N=2) Ph-service-access-point (N=1)	[ISO/IEC 7498-3]
3.1.41	(N)-service-access-point-address DL-service-access-point-address (N=2) Ph-service-access-point-address (N=1)	[ISO/IEC 7498-3]
3.1.42	peer-entities	[ISO/IEC 7498-3]
3.1.43	Ph-interface-control-information	[ISO/IEC 7498-3]
3.1.44	Ph-interface-data	[ISO/IEC 7498-3]
3.1.45	primitive name	[ISO/IEC 7498-3]
3.1.46	reassembling	[ISO/IEC 7498-3]
3.1.47	recombining	[ISO/IEC 7498-3]
3.1.48	reset	[ISO/IEC 7498-3]
3.1.49	responding-DL-address	[ISO/IEC 7498-3]
3.1.50	routing	[ISO/IEC 7498-3]
3.1.51	segmenting	[ISO/IEC 7498-3]
3.1.52	sequencing	[ISO/IEC 7498-3]
3.1.53	splitting	[ISO/IEC 7498-3]
3.1.54	synonymous name	[ISO/IEC 7498-3]
3.1.55	systems-management	[ISO/IEC 7498-3]

3.2 Service convention terms and definitions

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

- 3.2.1 acceptor
- 3.2.2 asymmetrical service
- 3.2.3 confirm (primitive);
requestor.deliver (primitive)
- 3.2.4 deliver (primitive)
- 3.2.5 DL-confirmed-facility
- 3.2.6 DL-facility
- 3.2.7 DL-local-view
- 3.2.8 DL-mandatory-facility
- 3.2.9 DL-non-confirmed-facility
- 3.2.10 DL-provider-initiated-facility
- 3.2.11 DL-provider-optional-facility
- 3.2.12 DL-service-primitive;
primitive
- 3.2.13 DL-service-provider
- 3.2.14 DL-service-user
- 3.2.15 DL-user-optional-facility
- 3.2.16 indication (primitive)
acceptor.deliver (primitive)
- 3.2.17 multi-peer
- 3.2.18 request (primitive);
requestor.submit (primitive)
- 3.2.19 requestor
- 3.2.20 response (primitive);
acceptor.submit (primitive)
- 3.2.21 submit (primitive)
- 3.2.22 symmetrical service
- 3.3 Common terms and definitions

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

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

3.3.1

DL-segment,
link,
local link

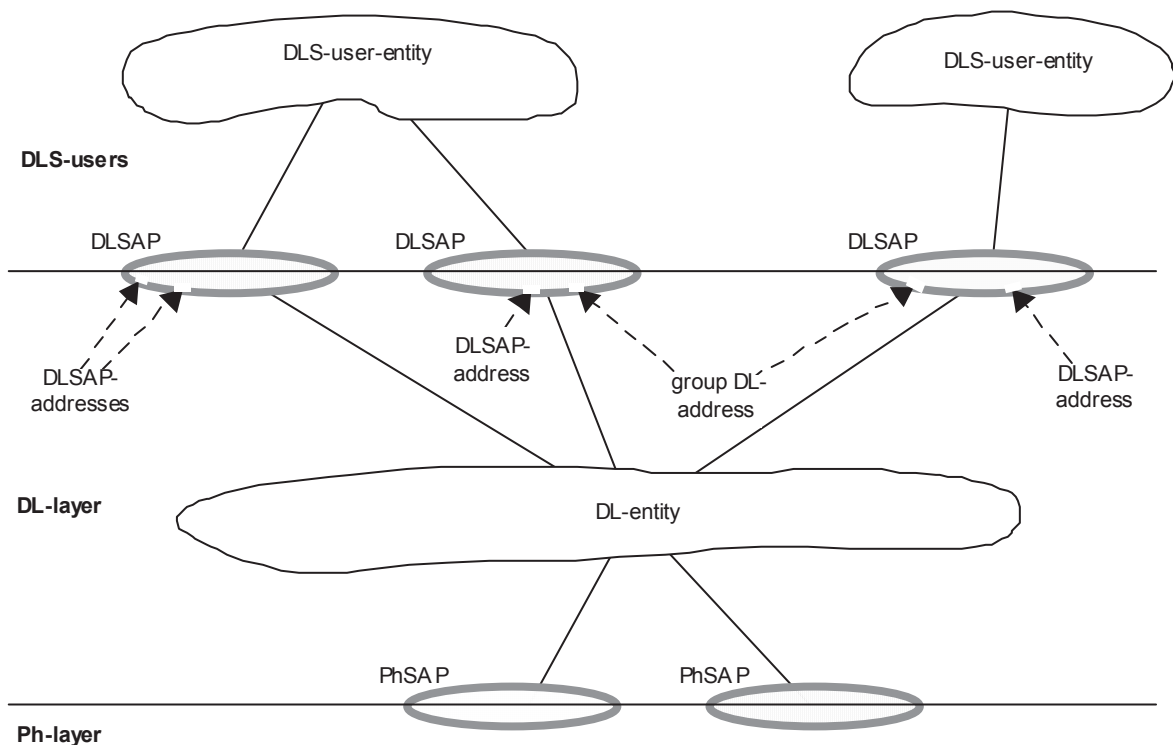
single DL-subnetwork in which any of the connected DLEs may communicate directly, without any intervening DL-relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the period(s) of attempted communication

3.3.2

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.)



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

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

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

Figure 1 – Relationships of DLSAPs, DLSAP-addresses and group DL-addresses

3.3.3

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.

3.3.4

(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.

3.3.5

extended link

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

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

3.3.6

frame

denigrated synonym for DLPDU

3.3.7

group DL-address

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

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

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

3.3.8

node

single DL-entity as it appears on one local link

3.3.9

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.

3.3.10

sending DLS-user

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

3.4 Additional Type 3 definitions

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

3.4.1

acknowledge DLPDU

reply DLPDU that contains no DLSDU

3.4.2

address extension

DLSAP address or region/segment address

3.4.3

bit time

time to transmit one bit

3.4.4

confirmed message exchange

complete data transfer with request and acknowledgement or response DLPDU

3.4.5

controller_type

hardware class of the communications entity

3.4.6

current master

token holder

3.4.7

data DLPDU

DLPDU that carries a DLSDU from a local DLS-user to a remote DLS-user

3.4.8

DL_status

status that specifies the result of the execution of the associated request

3.4.9

GAP

range of station (DLE) DL-addresses from this station (TS) to its successor (NS) in the logical token ring, excluding stations above HSA

3.4.10

GAP maintenance

registration of new Master and slave stations

3.4.11

isochronous mode

special operational mode that implies both a constant (isochronous) cycle with a fixed schedule of high and low priority messages, and the synchronization of the DLS-users with this constant (isochronous) cycle

3.4.12

local DLS-user

DLS-user that initiates the current service

3.4.13

message exchange

complete confirmed or unconfirmed data transfer

3.4.14

region/segment address

address extension that identifies a particular fieldbus subnetwork

Note 1 to entry: This supports DL-routing between fieldbuses.

3.4.15

request data

DLSDU provided by the remote DLS-user to the local DLS-user

3.4.16

remote DLE

addressed DLE of a service request (that is, the intended receiving DLE of any resulting send/request DLPDU)

3.4.17

remote DLS-user

addressed DLS-user of a service request (that is, the intended receiver of any resulting indication primitive)

3.4.18

reply DLPDU

DLPDU transmitted from a remote DLE to the initiating (local) DLE, and possibly other DLEs

Note 1 to entry: When the remote DLE is a Publisher, the reply DLPDU also can be sent to several remote DLEs.

3.4.19

response DLPDU

reply DLPDU that carries a DLSDU from a remote DLS-user to local DLS-user

3.4.20

send data

DLSDU provided by a local DLS-user to a remote DLS-user

3.4.21

send/request DLPDU

DLPDU that carries either a request for data or a DLSDU or both from a local DLS-user to a remote DLS-user

3.4.22

time master

device which is able to send clock synchronization DLPDUs

Note 1 to entry: Link devices have time master functionality.

3.4.23

time receiver

device which is able to be time synchronized by a time Master

3.4.24

token holder

Master station that controls bus access

3.4.25

token passing

medium access method, in which the right to transmit is passed from master station to master station in a logical ring

3.5 Common symbols and abbreviations

3.5.1 Data units

3.5.1.1	DLPDU	DL-protocol data unit
3.5.1.2	DLSDU	DL-service data unit
3.5.1.3	PhIDU	Ph-interface data unit
3.5.1.4	PhPDU	Ph-protocol data unit

3.5.2 Miscellaneous

3.5.2.1	DL-	data link layer (as a prefix)
3.5.2.2	DLCEP	DL-connection endpoint
3.5.2.3	DLE	DL-entity (the local active instance of the Data Link layer)
3.5.2.4	DLL	DL-layer
3.5.2.5	DLM-	DL-management (as a prefix)
3.5.2.6	DLMS	DL-management-service
3.5.2.7	DLS	DL-service
3.5.2.8	DLSAP	DL-service access point
3.5.2.9	FIFO	first-in first-out (queuing method)
3.5.2.10	LLC	logical link control
3.5.2.11	MAC	medium access control

3.5.2.12	OSI	open systems interconnection
3.5.2.13	Ph-	physical layer (as a prefix)
3.5.2.14	PhE	Ph-entity (the local active instance of the Physical layer)
3.5.2.15	PhL	Ph-layer
3.5.2.16	PhS	Ph-service
3.5.2.17	PhSAP	Ph-service access point
3.5.2.18	QoS	quality of service

3.6 Type 3 symbols and abbreviations

3.6.1	ACK	acknowledge(ment) DLPDU
3.6.2	ASM	active spare time message
3.6.3	ASP	active spare time period
3.6.4	Bus ID	bus identification, an address extension (region/DL-segment address) that identifies a particular bus as supporting routing between DL-segments
3.6.5	CRX	character receive execution
3.6.6	CS	clock synchronization
3.6.7	CTX	character transmit execution
3.6.8	DA	destination address of a DLPDU
3.6.9	DAE	destination address extension(s) of a DLPDU, which convey D_SAP_index and/or destination bus ID
3.6.10	D_SAP	destination service access point, the DLSAP associated with the remote DLS-user
3.6.11	D_SAP_index	destination service access point index – that component of a DLSAP address which designates a DLSAP and remote DLS-user within the remote DLE
3.6.12	DXM	data exchange multicast
3.6.13	ED	end delimiter of a DLPDU
3.6.14	EOA	End-of-Activity
3.6.15	EOD	End-of-Data
3.6.16	EODA	End-of-Data-and-Activity
3.6.17	EXT	address extension bit of a DLPDU
3.6.18	FC	frame control (frame type) field of a DLPDU
3.6.19	FCB	frame count bit of a DLPDU (FC field) used to eliminate lost or duplicated DLPDUs

3.6.20	FCV	frame count bit valid bit of a DLPDU, indicates whether the FCB is to be evaluated
3.6.21	FCS	frame check sequence (synchronous) or frame checksum (asynchronous)
3.6.22	FLC	fieldbus link control
3.6.23	G	GAP update factor, the number of token rotations between GAP maintenance (update) cycles
3.6.24	GAPL	GAP list containing the status of all stations in this station's GAP
3.6.25	IsoM	isochronous mode
3.6.26	Hd	Hamming distance, a measure of DLPDU integrity, the minimum number of bit errors that can cause acceptance of a spurious DLPDU
3.6.27	HSA	highest station address installed (configured) on this fieldbus
3.6.28	L	length of the information field, the part of a DLPDU that is checked by the FCS
3.6.29	LE	field giving the length of a DLPDU beyond the fixed part
3.6.30	LEr	field that repeats the length to increase DLPDU integrity
3.6.31	LMS	list of master stations
3.6.32	LR	local resource not available or not sufficient (DL/DLM_status of the service primitive)
3.6.33	LS	local service not activated at DL-service access point or local DLSAP not activated (DL/DLM_status of the service primitive)
3.6.34	lsb	least significant bit of a field or octet
3.6.35	max	the arithmetic maximum function
3.6.36	MCT	multicast
3.6.37	MP	message transfer message retry transfer periods
3.6.38	mr	number of retries
3.6.39	msb	most significant bit of a field or octet
3.6.40	MSRD	DLS: Send and Request Data with Multicast reply
3.6.41	mt	number of retries per token rotation
3.6.42	n	number of stations
3.6.43	NA	no acknowledgement/response (DL/DLM_status of the service primitive)
3.6.44	na	number of active stations
3.6.45	NIL	locally determined value
3.6.46	NO	not ok (DL/DLM_status of the service primitive)
3.6.47	np	number of passive stations

3.6.48	NR	no response DL-data acknowledgement negative and send data ok (DL_status of the service primitive)
3.6.49	NRZ	non-return-to-zero (PhL), an encoding technique where transitions occur only when successive data bits have different values
3.6.50	NS	next station, the station to which this master will pass the token
3.6.51	OK	service finished according to the rules (DL/DLM_status of the service primitive)
3.6.52	PhICI	PhL Interface Control Information [ISO/IEC 7498-1]
3.6.53	PhPCI	PhL Protocol Control Information [ISO/IEC 7498-1]
3.6.54	PON	power on transition occurs at a station
3.6.55	PS	previous station, the station which passes the token to this master station
3.6.56	PSP	passive spare time period
3.6.57	RDH	response DL-data high and no resource for send data (DL/DLM_status of the service primitive)
3.6.58	RDL	response DL/DLM-data low and no resource for send data (DL/DLM_status of the service primitive)
3.6.59	Res	reserved
3.6.60	RET	retry
3.6.61	RR	no resource for send data and no response DL-data available (negative acknowledgement) (DL/DLM_status of the service primitive)
3.6.62	RS	no service, or no service activated at remote DLSAP (negative acknowledgement) (DL/DLM_status of the service primitive)
3.6.63	RSYS	system message rate (in message transfer periods per second) at which confirmed DL-message exchanges are performed
3.6.64	SA	source address of a DLPDU
3.6.65	SAE	source address extension(s) of a DLPDU, which convey S_SAP_index and/or source bus ID
3.6.66	SC	single character acknowledge DLPDU
3.6.67	SD1 to SD4	start delimiters of asynchronous DLPDU transmission
3.6.68	SDA	Send Data with Acknowledge (DL-service)
3.6.69	SDA_H/L	Send Data with Acknowledge high/low (DLPDU Function)
3.6.70	SDX	start delimiter of asynchronous or synchronous DLPDU transmission
3.6.71	SDL1 to SDL5	start delimiters of synchronous DLPDU transmission
3.6.72	SDN	Send Data with No Acknowledge (DL-service)
3.6.73	SDN_H/L	Send Data with No Acknowledge high/low (DLPDU Function)
3.6.74	SM	state machine

3.6.75	SOA	Start-of-Activity
3.6.76	SRC	send receive control
3.6.77	SRD	Send and Request Data with Reply (DL-service)
3.6.78	SRD_H/L	Send and Request Data with Reply high/low (DLPDU Function)
3.6.79	SRU	send receive unit
3.6.80	S_SAP	source service access point, the DLSAP associated with the initiating local DLS-user
3.6.81	S_SAP_index	source service access point index – a component of a DLSAP-address which designates that DLSAP within the DLE at which the transaction is being initiated
3.6.82	Stn	station, a device implementing a DLE with a fieldbus DL-address
3.6.83	SYN	synchronizing bits of a DLPDU (period of idle), which guarantees the specified DLPDU integrity and allows for receiver synchronization
3.6.84	TA/R	time to transmit an acknowledgement/response DLPDU
3.6.85	TASM	ASM message time
3.6.86	tBIT	bit time
3.6.87	TCSI	clock synchronization interval time
3.6.88	TcT	isochronous cycle time
3.6.89	TGUD	GAP update time
3.6.90	TID	idle time
3.6.91	TIM	timer state machine
3.6.92	TMP	message transfer period
3.6.93	TP	token transfer period
3.6.94	TPSP	passive spare time
3.6.95	TPTG	post transmission gap time
3.6.96	TQUI	quiet time
3.6.97	TRCT	real isochronous cycle time
3.6.98	TRD	receive delay time
3.6.99	TRDY	ready time
3.6.100	TRES	spare time
3.6.101	TRR	real rotation time
3.6.102	TS	this station
3.6.103	TS/R	send/request DLPDU time
3.6.104	Tsd	send delay time

3.6.105	TSDI	station delay of initiator
3.6.106	TSDR	station delay of responder
3.6.107	TSET	setup time
3.6.108	Tsh	time shift
3.6.109	TSL	slot time
3.6.110	TSM	safety margin time
3.6.111	TSR	system reaction time
3.6.112	TSYN	synchronization time
3.6.113	TSYNI	synchronization interval time
3.6.114	TTC	token cycle time
3.6.115	TTD	transmission delay time
3.6.116	TTF	token DLPDU time
3.6.117	TTH	token holding time
3.6.118	TTO	timeout time
3.6.119	TTP	token transfer period
3.6.120	TTR	target rotation time
3.6.121	UART	universal asynchronous receiver/transmitter
3.6.122	UC	UART character
3.6.123	UE	negative acknowledgement, remote user interface error (DL/DLM_status of the service primitive)

4 Common DL-protocol elements

4.1 Frame check sequence

4.1.1 General

Any reference to bit K of an octet is a reference to the bit whose weight in a one-octet unsigned integer is 2^k .

NOTE 1 This is sometimes referred to as "little endian" bit numbering.

As in other International Standards (see Note 2), DLPDU-level error detection is provided by calculating and appending a multi-bit frame check sequence (FCS) to the other DLPDU fields during transmission to form a "systematic code word"¹⁾ of length n consisting of k DLPDU message bits followed by $n - k$ redundant bits, and by calculating during reception that the message and concatenated FCS form a legal (n, k) code word. The mechanism for this checking is as follows:

NOTE 2 For example, ISO/IEC 8802.

¹⁾ W. W. Peterson and E. J. Weldon, Jr., *Error Correcting Codes* (2nd edition), MIT Press, Cambridge, 1972.

The generic form of the generator polynomial for this FCS construction is specified in equation (4) and the polynomial for the receiver's expected residue is specified in equation (9). The specific polynomials for DL-protocol type 3 are specified in Table 1. An exemplary implementation is shown in Annex B.

Table 1 – FCS length, polynomials and constants by Type 3 synchronous

Item	Value
$n-k$	16
$G(x)$	$X^{16} + X^{12} + X^{11} + X^{10} + X^8 + X^7 + X^6 + X^3 + X^2 + X + 1$ (see Notes 1, 2, 3)
$R(x)$	$X^{15} + X^{14} + X^{13} + X^9 + X^8 + X^7 + X^4 + X^2$ (see Note 4)
<p>NOTE 1 Code words $D(X)$ constructed from this $G(X)$ polynomial have Hamming distance 4 for lengths ≤ 344 octets and Hamming distance 5 for lengths ≤ 15 octets.</p> <p>NOTE 2 This $G(X)$ polynomial is relatively prime to all, and is thus not compromised by any, of the polynomials commonly used in DCEs (modems): the differential encoding polynomial $1 + X^{-1}$ and all primitive scrambling polynomials of the form $1 + X^{-j} + X^{-k}$.</p> <p>NOTE 3 This $G(X)$ polynomial is the optimal 16-bit polynomial for burst error detection over DLPDUs of 300 octets or less when the statistics of the error burst have a Poisson distribution (as is the usual case).</p> <p>NOTE 4 The remainder $R(x)$ is 1110 0011 1001 0100 (X^{15} to X_0, respectively) in the absence of errors.</p>	

4.1.2 At the sending DLE

The original message (that is, the DLPDU without an FCS), the FCS, and the composite message code word (the concatenated DLPDU and FCS) shall be regarded as vectors $M(X)$, $F(X)$, and $D(X)$, of dimension k , $n - k$, and n , respectively, in an extension field over Base Galois Field(2). If the message bits are $m_1 \dots m_k$ and the FCS bits are $f_{n-k-1} \dots f_0$, where

$m_1 \dots m_8$ form the first octet sent,
 $m_{8N-7} \dots m_{8N}$ form the N th octet sent,
 $f_7 \dots f_0$ form the last octet sent, and
 m_1 is sent by the first PhL symbol(s) of the message and f_0 is sent by the last PhL symbol(s) of the message (not counting PhL framing information),

NOTE 1 This "as transmitted" ordering is critical to the error detection properties of the FCS.

then the message vector $M(X)$ shall be regarded to be

$$M(X) = m_1X_{k-1} + m_2X_{k-2} + \dots + m_{k-1}X_1 + m_k \quad (1)$$

and the FCS vector $F(X)$ shall be regarded to be

$$\begin{aligned} F(X) &= f_{n-k-1}X_{n-k-1} + \dots + f_0 \\ &= f_{15}X_{15} + \dots + f_0 \end{aligned} \quad (2)$$

The composite vector $D(X)$, for the complete DLPDU, shall be constructed as the concatenation of the message and FCS vectors

$$\begin{aligned} D(X) &= M(X)X_{n-k} + F(X) \\ &= m_1X_{n-1} + m_2X_{n-2} + \dots + m_kX_{n-k} + f_{n-k-1}X_{n-k-1} + \dots + f_0 \\ &= m_1X_{n-1} + m_2X_{n-2} + \dots + m_kX_{16} + f_{15}X_{15} + \dots + f_0 \end{aligned} \quad (3)$$

The DLPDU presented to the PhL shall consist of an octet sequence in the specified order.

The redundant check bits $f_{n-k-1} \dots f_0$ of the FCS shall be the coefficients of the remainder $F(X)$, after division by $G(X)$, of $L(X) (X_k + 1) + M(X) X_{n-k}$

where $G(X)$ is the degree $n-k$ generator polynomial for the code words

$$\begin{aligned} G(X) &= X_{n-k} + g_{n-k-1}X_{n-k-1} + \dots + 1 \\ &= X_{16} + X_{12} + X_{11} + X_{10} + X_8 + X_6 + X_3 + X_2 + X + 1 \end{aligned} \quad (4)$$

and $L(X)$ is the maximal weight (all ones) polynomial of degree $n-k-1$

$$\begin{aligned} L(X) &= \frac{X^{n-k} + 1}{X + 1} = X_{n-k-1} + X_{n-k-2} + \dots + X + 1 \\ &= X_{15} + X_{14} + X_{13} + X_{12} + \dots + X_2 + X + 1 \end{aligned} \quad (5)$$

That is,

$$F(X) = L(X) (X_k + 1) + M(X) X_{n-k} \text{ (modulo } G(X)) \quad (6)$$

NOTE 2 The $L(X)$ terms are included in the computation to detect initial or terminal message truncation or extension by adding a length-dependent factor to the FCS.

NOTE 3 As a typical implementation when $n-k = 16$, the initial remainder of the division is preset to all ones. The transmitted message bit stream is multiplied by X_{n-k} and divided (modulo 2) by the generator polynomial $G(X)$, specified in equation (4). The ones complement of the resulting remainder is transmitted as the $(n-k)$ -bit FCS, with the coefficient of X_{n-k-1} transmitted first.

4.1.3 At the receiving DLE

The octet sequence indicated by the PhE shall be concatenated into the received DLPDU and FCS, and regarded as a vector $V(X)$ of dimension u

$$V(X) = v_1X_{u-1} + v_2X_{u-2} + \dots + v_{u-1}X + v_u \quad (7)$$

NOTE 1 Because of errors u can be different than n , the dimension of the transmitted code vector.

A remainder $R(X)$ shall be computed for $V(X)$, the received DLPDU and FCS, by a method similar to that used by the sending DLE (see 4.1.2) in computing $F(X)$

$$\begin{aligned} R(X) &= L(X) X_u + V(X) X_{n-k} \text{ (modulo } G(X)) \\ &= r_{n-k-1}X_{n-k-1} + \dots + r_0 \end{aligned} \quad (8)$$

Define $E(X)$ to be the error code vector of the additive (modulo-2) differences between the transmitted code vector $D(X)$ and the received vector $V(X)$ resulting from errors encountered (in the PhS provider and in bridges) between sending and receiving DLEs.

$$E(X) = D(X) + V(X) \quad (9)$$

If no error has occurred, so that $E(X) = 0$, then $R(X)$ will equal a non-zero constant remainder polynomial

$$R_{ok}(X) = L(X) X_{n-k} \text{ (modulo } G(X)) \quad (10)$$

whose value is independent of $D(X)$. Unfortunately $R(X)$ will also equal $R_{ok}(X)$ in those cases where $E(X)$ is an exact non-zero multiple of $G(X)$, in which case there are “undetectable” errors. In all other cases, $R(X)$ will not equal $R_{ok}(X)$; such DLPDUs are erroneous and shall be discarded without further analysis.

NOTE 2 As a typical implementation, the initial remainder of the division is preset to all ones. The received bit stream is multiplied by X_{n-k} and divided (modulo 2) by the generator polynomial $G(X)$, specified in equation (4).

5 Overview of the DL-protocol

NOTE Annex A specifies a number of finite state machines used by the DLE to provide its low-level and high-level protocol functions. The specification of Annex A is complementary to the textual specification in this and related clauses in the body of this document. In case of conflict the requirements of Annex A take precedence.

5.1 General

From the requirements of the various application fields, for example, process control, factory automation, power distribution, building automation, primary process industry etc., the following characteristic features of the fieldbus data-link protocol are resulting (see Table 2).

Table 2 – Characteristic features of the fieldbus data-link protocol

Feature	Description
Station types	Masters (active stations, with bus access control); Slaves (passive stations, without bus access control); preferably at most 32 masters, optionally up to 127, if the applications are not time critical
Station addressing	0 to 127 (127 = global addresses for broad-cast and multicast messages), address extension for region/DL-segment address and service access address (DLSAP), 6 bit each
Bus access	Hybrid: decentralized and central; "token-passing" between master stations and "Master-Slave" between Master and slave stations
Data transfer services	Send Data with/without Acknowledge Send and Request Data with Reply Send and Request Data with Multicast Reply Clock Synchronization
DLPDU length	max. 255 octets per DLPDU, 0 to 246 octets for each data unit without address extension
Transmission speed	Depending on network topology and cable lengths, for example, step-wise from 9,6 to 12 000 kBit/s
Transmission characteristic	Half duplex, asynchronous and synchronous transmission
Data integrity asynchronous transmission	Messages with Hamming distance (Hd) = 4, sync slip detection, special sequence to avoid loss or duplication of data
Data integrity synchronous transmission	Hamming distance (Hd) = 4 for DLPDU lengths shorter than 255 octets and Hd = 5 for lengths shorter than 15 octets, special sequence to avoid loss or duplication of data
NOTE 1 The DLPDU format for asynchronous transmission is the format FT 1.2 (asynchronous transmission with start-stop synchronization) for Telecontrol Equipment and Systems, which is specified in IEC 60870-5-1.	
NOTE 2 The DLPDU format for synchronous transmission is based on octet characters.	

5.2 Overview of the medium access control and transmission protocol

The fieldbus data-link layer uses controlled medium access accomplished by a hybrid medium access method: a decentralized method according to the principle of token-passing is underlain by a central method according to the master-slave principle. Medium access control may be exercised by each master station (active station). The token-passing is characterized by the following features:

a) Token-passing allows fair media access for all token holders.

EXAMPLE When four token holders produce the same amount of similar priority data they will share the media so that on average each of them can use 25 % of the available message transfer time. With the token-passing procedure, rules exist to share the message transfer time between the token holders without discrimination of any of them. In case of usage of the whole of the available token holding time by one token holder in one token rotation this token holder is limited to one high priority message in the next token rotation after which it has to transfer the token immediately.

b) Token-passing guarantees short reaction time.

EXAMPLE For urgent messages, a maximum delay is specified for delivery of the information. Thus, a configurable time (T_{TR}) specifies the target rotation time. Independent of the number of token holders and the amount of messages that have to be sent, at least one urgent message can be sent by each token holder. Thus, a short reaction time is guaranteed for one urgent message from each token holding station in each token holding period.

c) Token-passing allows flexible (re-)configuration.

EXAMPLE When a token holder is switched on or off, it will be automatically included or excluded in the logical ring. In the next token rotation after detection and inclusion in the logical token ring, the new token holder has the same rights to send messages as the other token holders. The sharing of the bus message transfer time is organized automatically without changing of parameters of the other token holders.

Medium access control may be exercised by each master station (active station) if the station has the token. The token is passed from master station to master station in a logical ring and thus determines the instant, when a master station may access the medium. Controlled token passing is managed by each station knowing its predecessor (previous station, PS), the station from which it receives the token. Furthermore, each station knows its successor (next station, NS), that is, the station to which the token is transmitted, and its own address (This station, TS). Each master station determines the PS and NS addresses after the initialization of the operating parameters for the first time and then later dynamically according to the algorithm described in 5.3.2.4.

The Master-Slave principle is characterized by the following features:

Communication is always initiated by a master station which has the permission for medium access, the token. slave stations (passive stations) act neutrally in respect to medium access, that is, they do not transmit independently but only on request. If the logical ring consists of only one Master and several slave stations then it is a pure Master-Slave system.

The following error conditions, exceptions and operational states in the system are dealt with:

- multiple tokens,
- lost token,
- error in token passing,
- duplicate station addresses,
- stations with faulty transmitter or receiver,
- adding and removing stations during operation,
- any combinations of master and slave stations.

5.3 Transmission modes and DL-entity

5.3.1 Overview

The exchange of messages takes place confirmed or unconfirmed. A confirmed message exchange consists of a master station's send/request DLPDU and the associated acknowledgement or response DLPDU of a Master or a slave station. User data may be transmitted in the send/request DLPDU as well as in the response DLPDU. The acknowledgement DLPDU does not contain any user data (for DLPDU formats see Clause 7).

An unconfirmed message exchange takes place only in case of token transmission and in case of the transmission of data without acknowledgement (for example, necessary for broadcast messages). In both modes of operation, there is no acknowledgement. In broadcast messages a master station (initiator) addresses all other stations at the same time by means of a global address (highest station address, all address bits are binary "1").

All stations except the respective token holder (initiator) shall in general monitor all requests. The stations acknowledge or respond only when they are addressed. The acknowledgement or response shall arrive within a predefined time, the slot time, otherwise the initiator repeats, depending on the predefined retry limit, the request if it is not a "first request" (see 6.4, FCB). A new request or a token shall not be issued by the

initiator before the expiration of a waiting period after receiving an acknowledge or response, the idle time (see 5.5).

If the responder does not acknowledge or respond after a predefined number of retries (see Table 5), it is marked as "non-operational". If a responder is "non-operational", a later unsuccessful request will not be repeated.

The modes of transmission operation define the sequence of the message transfer periods. Three modes are distinguished:

- 1) Token handling.
- 2) Send operation.
- 3) Send and request operation.

5.3.2 Token procedures

5.3.2.1 Token circulation

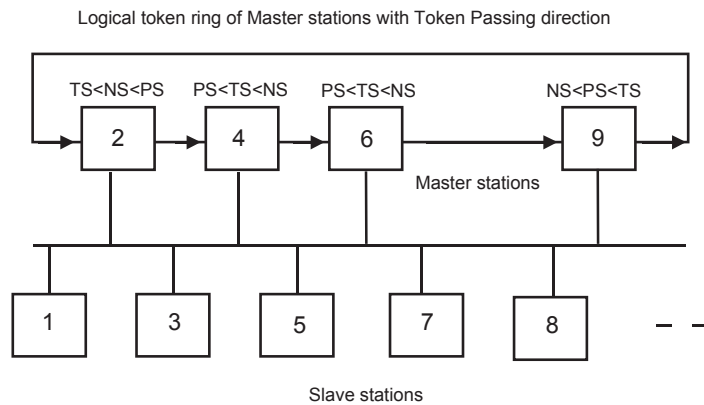
The token is passed from master station to master station in ascending numerical order of station addresses by means of the token DLPDU (see 7.4). To close the logical token ring, the station with the highest address passes the token to the station with the lowest address, see Figure 2.

5.3.2.2 Token reception

If a master station (TS) receives a token DLPDU addressed to itself from a station which is registered as Previous station (PS) in its list of master stations (LMS), it owns the token and may execute message transfer periods. The LMS is generated in a master station in the "Listen-Token" state (see 8.2.4) after power on and is updated and corrected, if necessary, later on upon each receipt of a token DLPDU.

If the token transmitter is not the registered PS, the addressee assumes an error and shall not accept the token. Only a subsequent retry of the same PS is accepted and results in the token receipt, because the token receiver shall assume now that the logical ring has changed. It replaces the originally recorded PS in its LMS by the new one.

Figure 2 shows the logical token-passing ring.



where

TS is this station (address);

PS is previous station (address);

NS is next station (address);

master stations are 2, 4, 6 and 9 (addresses as an example);

slave stations are 1, 3, 5, 7 and 8 (addresses as an example).

Figure 2 – Logical token-passing ring

5.3.2.3 Token transmission

After the master station has finished its message transfer periods – contingent maintenance of the GAP station list (GAPL, see 5.3.2.4) included – it passes the token to its successor (NS) by transmitting the token DLPDU. The functionality of its transceiver is checked by simultaneous monitoring (see 8.2.11, "Pass_Token" state).

If, after transmitting the token DLPDU and after expiration of the synchronization time within the slot time (see 5.5), the token transmitter receives a valid DLPDU, that is, a DLPDU header without any errors, it assumes that its NS owns the token and executes message transfer periods. If the token transmitter receives an invalid DLPDU, it assumes that another master station is transmitting. In both cases it ceases monitoring the token passing and retires, that is, it enters the "Active_Idle" state (see 8.2.5).

If the token transmitter does not recognize any bus activity within the slot time, it repeats the token DLPDU and waits another slot time. It retires thereafter, if it recognizes bus activity within the second slot time. Otherwise, it repeats the token DLPDU to its NS for a last time. If, after this second retry, it recognizes bus activity within the slot time, it retires.

If, after the second retry, there is no bus activity, the token transmitter tries to pass the token to the next but one master station (NS of NS). It continues repeating this procedure until it has found a successor from its LMS. If it does not succeed, the token transmitter assumes that it is the only one left in the logical token ring and transmits the token to itself. If it finds a NS again in a later station registration, it tries again to pass the token.

5.3.2.4 Addition and removal of stations

Master and slave stations may be connected to or disconnected from the transmission medium at any moment. Each master station in the logical token ring is responsible for the addition of new stations in the range from the own station address (TS) to the next station (NS), excluding TS and NS. This address range is called GAP and is represented in the GAP List (GAPL), except the address range between Highest Station Address (HSA: 2 to 126) and 127, which does not belong to the GAP.

Each master station in the logical token ring examines its address range (all GAP addresses) after expiration of the GAP update timer (see 5.5.3.11) for changes concerning Master and slave stations. This is accomplished by examining one address per token receipt, using the "Request DL Status with Reply" request DLPDU (see Table 3, b7=1, Code-No 9: Format 7.1.1 a) and 7.1.2 a)).

Upon receiving the token, GAP maintenance starts immediately after all queued message transfer periods have been executed, if there is still transmission time available (see 5.3.2.6). Otherwise, GAP maintenance starts upon the next or the consecutive token receipts after the high priority message transfer periods and other low priority services invoked before the previous GAP maintenance have been performed (see 5.3.2.7). In realizations, care is necessary to ensure that GAP maintenance and low priority message transfer periods do not block each other.

GAP addresses are examined in ascending order, except the GAP which surpasses the HSA. For example, if the HSA and address 0 are not used by a master station, the master station with the highest address examines address 0 after checking the HSA.

If a station acknowledges positively with the DL status "Master station not ready to enter logical token ring" or "Slave station" (see Table 3, b7=0, Code-No 0, no SC, and Figure 20), it is accordingly marked in the GAPL and the next address is checked. If a station answers with the state "Master station ready to enter logical token ring", the token holder changes its GAPL and LMS and passes the token to the new NS. This station, which has newly been admitted to the logical token ring, has already built up its LMS, when it was in the "Listen_Token" state, so that it is able to determine its GAP range and its NS.

If a station answers with the DL status "Master station in logical token ring", then the token holder does not change its GAP and passes the token to the NS given in the LMS. Thus the skipped master station may retire from the bus in case of permanent not receiving the token. In this case the master station shall enter the "Listen_Token" state. In this state it generates a new LMS and remains in this state until it is addressed once more by a "Request DL Status with Reply" transmitted by its predecessor (PS).

Stations which were registered in the GAPL and which do not respond to a "Request DL Status with Reply" are removed from the GAPL and are recorded as unused station addresses.

Due to performance requirements repeated requests of "Request DL Status with Reply" are not desired.

5.3.2.5 (Re)initialization of the logical token ring

Initialization is primarily a special case of updating the LMS and GAPL. If after power on (PON) of a master station a time-out is encountered in the "Listen_Token" state (no bus activity within Time-out Time T_{TO} (see 5.5)), then the master station shall claim the token ("Claim_Token" state) and start initialization.

When the entire fieldbus system is started, the master station with the lowest station address starts initialization. By transmitting two token DLPDUs addressed to itself (DA = SA = TS) it informs any other master stations (entering a NS into their LMS) that it is now the only station in the logical token ring. Then it transmits a "Request DL Status with Reply" DLPDU to each station in an incrementing address sequence, in order to register other stations. If a station responds with "Master station not ready to enter logical token ring" or with "Slave station" it is entered in the GAPL. The first master station, which answers with "Master station ready to enter logical token ring", is registered as NS in the LMS and thus closes the GAP range of the token holder. Then the token holder passes the token to its NS.

Reinitialization becomes necessary after loss of the token, which causes a time-out (no bus activity). In this case, an entire bus initialization sequence is not required, because LMS and GAPL already exist in the master stations. The time-out expires first in the master station with the lowest address. It takes the token and starts executing regular message transfer periods or passes the token to its NS.

5.3.2.6 Token rotation time

After receiving a token, the DL-entity may carry out high priority and low priority message transfer periods according to the token rotation time. The token rotation time is measured by using the token-rotation-timer. At the beginning the token-rotation-timer is loaded with the target rotation time TTR and decremented with each bit time. The token-rotation-timer stops if the value zero is reached.

The token rotation time shall be measured according to the following rules:

- immediately after token reception the master station shall read the current value of the token-rotation-timer (token holding time TTH) to calculate the real rotation time TRR (difference between the target rotation time and the current value of token-rotation-timer) and shall start the token-rotation-timer with the value target rotation time (TTR);
- the TRR represents always the token rotation time of the last token rotation (from the viewpoint of this station).

A system's minimum target rotation time depends on the number of master stations and thus on the token transfer period (TTP) and the duration of high priority message transfer periods (high TMP). The predefined target rotation time TTR shall also contain sufficient time for low priority message transfer periods and a safety margin for potential retries.

In order to keep within the system reaction time required by the field of application, the target rotation time TTR of the token in the logical ring shall be specified.

The system reaction time is defined as the maximum time interval (worst case) between two consecutive high priority message transfer periods of a master station, measured at the DLS-user interface at maximum bus load.

In order to achieve a target rotation time as short as possible, it is recommended for the DLS-user (see IEC 61158-5-3), to declare only important data as high priority message transfer periods and to restrict their length (for example, ≤ 32 octets for the DLSDU, see 6.6).

If the transfer periods defined in 5.6 (equations (52) and (59) as well as (53) and (60)) are included and possible retries are taken into consideration, the operating parameter "target rotation time TTR" (see 5.6 and Table 5), which is necessary for initialization (min TTR), is calculated for the DLS-user as follows:

$$\min TTR = na \times TTP + (na + 1) \times \text{high TMP} + k \times \text{low TMP} + mt \times TRMP \quad (11)$$

where

- na is the number of master stations;
- k is the estimated number of low priority message transfer periods per token rotation;
- TTP is the token transfer period (see 5.6.1.1 and 5.6.2.1);
- TMP is the message transfer period, depending on DLPDU length (see 5.6.1.2 and 5.6.2.2);
- mt is the numbers of message retry transfer periods per token rotation;
- TRMP is the message retry transfer period.

The first term contains one token transfer period per master station. The second term contains one high priority message transfer period for $N+1$ master stations. The third term contains the estimated number of low priority message transfer periods per token rotation. The fourth term serves as a safety margin for potential retries. The maximum reaction time for high priority message transfer periods is guaranteed for all bus loads.

5.3.2.7 Message priorities

In the parameter service_class of the DL services the DLS-user (application layer) can choose between two priorities: low and high. The priority is passed to the DLE with the service request.

After token reception, each master station may always execute **one** high priority message transfer period including retries in the case of an error independently of the token holding time T_{TH} .

Further high or low priority message transfer periods may be executed according to the following rules if T_{TH} is still available (see 5.5.5).

- High or low priority messages may be carried out if the calculated real rotation time (T_{RR}) is less than the current value of the token-rotation-timer before the instant of execution of message sending.
- Once a high or low priority message transfer period is started, it is always completed, including any required retry (retries), even if the token-rotation-timer is less than or equal to the value of T_{RR} during the execution.
- If there is no T_{TH} available (the T_{RR} is greater than the current value of the token-rotation-timer before the instant of execution of message sending) then the token shall be passed to NS immediately.

NOTE 1 The prolongation of the token holding time T_{TH} automatically results in a shortening of transmission time for message transfer periods at the next token receipt.

NOTE 2 For further explanation, refer to Annex A and Annex C.

5.3.3 Send or send/request mode

In the send or send/request mode, single message transfer periods are conducted sporadically. The master station's DL-entity initiates this mode due to a local user's request upon receipt of the token. If there are several requests, this mode of operation may be continued until the maximum allowed token holding time expires.

5.4 Service assumed from the PhL

5.4.1 Asynchronous transmission

5.4.1.1 PhS transmission and reception services

The PhL data service includes two service primitives. A request primitive is used to request a service by the DL-entity; an indication primitive is used to indicate a reception to the DL-entity. The names of the respective primitives are as follows:

Ph-ASYN-DATA request

Ph-ASYN-DATA indication

The temporal relationship of the primitives is shown in Figure 3.

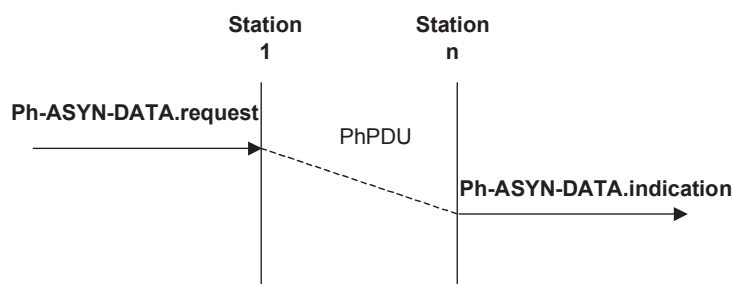


Figure 3 – PhL data service for asynchronous transmission

5.4.1.2 Detailed specification of the service and message exchange

This subclause describes in detail the service primitives and the related parameters in an abstract way. The parameters contain information needed by the PhL-entity.

Parameters of the primitives:

Ph-ASYN-DATA request (DL_symbol)

The parameter DL_symbol shall have one of the following values:

- a) ZERO corresponds to a binary "0",
- b) ONE corresponds to a binary "1",
- c) SILENCE disables the transmitter when no valid DL symbol is to be transmitted.

The Ph-ASYN-DATA request primitive is passed from the DL-entity to the PhL-entity to request that the given symbol shall be sent to the fieldbus medium.

The reception of this primitive shall cause the PhL-entity to attempt encoding and transmission of the DL-symbol.

The Ph-ASYN-DATA request is a primitive, which shall only be generated once per DL-symbol period (tBIT). The PhL-entity may confirm this primitive with a locally defined confirmation primitive.

Ph-ASYN-DATA indication (DL_symbol)

The parameter DL_symbol shall have one of the following values:

- ZERO corresponds to a binary "0",
- ONE corresponds to a binary "1".

The Ph-ASYN-DATA indication primitive is passed from the PhL-entity to the DL-entity to indicate that a DL-symbol was received from the fieldbus medium.

The Ph-ASYN-DATA indication is a primitive, which shall only be generated once per received DL-symbol period (tBIT).

5.4.2 Synchronous transmission

5.4.2.1 General

This subclause defines the assumed physical service (PhS) primitives and their constraints on use by the DLE.

NOTE Proper layering requires that an (N+1)-layer entity not be concerned with, and that an (N)-service interface not overly constrain, the means by which an (N)-layer provides its (N)-services. Thus the Ph-service interface does not require DLEs to be aware of internal details of the PhE (for example, preamble, postamble and DLPDU delimiter signal patterns, number of bits per baud), and do not prevent the PhE from using appropriate evolving technologies.

5.4.2.2 Assumed primitives of the PhS

The granularity of transmission in the fieldbus protocol is one octet. This is the granularity of PhS-user data and timing information exchanged at the PhL-DLL interface.

5.4.2.2.1 PhS characteristics reporting service

The PhS is assumed to provide the following service primitive to report essential PhS characteristics used in DLL transmission, reception, and scheduling activities:

Ph-CHARACTERISTICS indication (minimum-data-rate, framing-overhead)

where

minimum-data-rate – specifies the effective minimum rate of data conveyance in bits per second, including any timing tolerances, of any PhE on the local link.

NOTE 1 A PhE with a nominal data rate of 1 Mbit/s $\pm$ 0,01 % would specify a minimum data rate of 0,9999 Mbit/s.

framing-overhead – specifies the maximum number of bit periods, where
period = 1/data rate,
used in any transmission for PhPDUs which do not directly convey data (for example, PhPDUs conveying preamble, DLPDU delimiters, postamble, inter-DLPDU “silence”, and so on).

NOTE 2 If the framing overhead is F and two DL message lengths are L₁ and L₂, then the time to send two immediately consecutive messages of lengths L₁ and L₂ will be at least as great as the time required to send one message of length L₁ + F + L₂.

If this framing-overhead is more than the DLEs configured per-DLPDU-PhL-overhead, V(PhLO), then the DLE shall report this discrepancy to DL-management and shall not issue Ph-DATA requests while the discrepancy exists.

NOTE 3 This restriction prohibits DLE transmission while this discrepancy exists. The DLEs local station management may remedy this discrepancy by reconfiguring V(PhLO) to a greater value.

5.4.2.2.2 PhS transmission and reception services

The PhS is assumed to provide the following service primitives for transmission and reception:

Ph-DATA request (class, data);

Ph-DATA indication (class, data);

Ph-DATA confirm (status)

where

class – specifies the Ph-interface-control-information (PhICI) component of the Ph-interface-data-unit (PhIDU). For a Ph-DATA request, its possible values are

START-OF-ACTIVITY – transmission of the PhPDUs which precede Ph-user data should commence;

DATA – the single-octet value of the associated data parameter should be transmitted as part of a continuous correctly-formed transmission;

END-OF-DATA-AND-ACTIVITY – the PhPDUs which terminate Ph-user data should be transmitted after the last preceding octet of Ph-user data, culminating in the cessation of active transmission;

For a Ph-DATA indication, its possible values are:

START-OF-ACTIVITY – reception of an apparent transmission from one or more PhEs has commenced;

DATA – the associated data parameter was received as part of a continuous correctly-formed reception;

END-OF-DATA – the ongoing continuous correctly formed reception of Ph-user data has concluded with correct reception of PhPDUs implying END-OF-DATA;

END-OF-ACTIVITY – the ongoing reception (of an apparent transmission from one or more PhEs) has concluded, with no further evidence of PhE transmission;

END-OF-DATA-AND-ACTIVITY – simultaneous occurrence of END-OF-DATA and END-OF-ACTIVITY;

data – specifies the Ph-interface-data (PhID) component of the PhIDU. It consists of one octet of Ph-user data to be transmitted (Ph-DATA request) or which was received successfully (Ph-DATA indication).

status – specifies either success or the locally detected reason for inferring failure.

The Ph-DATA confirm primitive provides the critical physical timing feedback necessary to inhibit the DLE from starting a second transmission before the first is complete. The final Ph-DATA confirm of a transmission shall not be issued until the PhE has completed the current transmission.

5.4.2.3 Notification of PhS characteristics

The PhE has the responsibility for notifying the DLE of those characteristics of the PhS which are relevant to DLE operation. This notification is accomplished by the PhE by issuing a single Ph-CHARACTERISTICS indication primitive at each of the PhEs PhSAPs at PhE startup.

5.4.2.4 Transmission of Ph-user data

The PhE determines the timing of all transmissions. When a DLE has a DLPDU to transmit, and the DL-protocol gives that DLE the right to transmit, then the DLE shall send the DLPDU, including a concatenated FCS, by making a well-formed sequence of Ph-DATA requests, consisting of a single request specifying START-OF-ACTIVITY; followed by three to 300 consecutive requests, inclusive, specifying DATA; and concluded by a single request specifying END-OF-DATA-AND-ACTIVITY.

The PhE signals its completion of each Ph-DATA request, and its readiness to accept a new Ph-DATA request, with a Ph-DATA confirm primitive; the status parameter of the Ph-DATA confirm primitive conveys the success or failure of the associated Ph-DATA request. A second Ph-DATA request should not be issued until after the Ph-DATA confirm corresponding to the first request has been received from the PhE.

5.4.2.5 Reception of Ph-user data

The PhE reports a received transmission with a well-formed sequence of Ph-DATA indications, which shall consist of either

- a) a single indication specifying START-OF-ACTIVITY; followed by consecutive indications specifying DATA; followed by a single indication specifying END-OF-DATA; and concluded by a single indication specifying END-OF-ACTIVITY, or
- b) a single indication specifying START-OF-ACTIVITY; followed by consecutive indications specifying DATA; followed by a single indication specifying END-OF-DATA-AND-ACTIVITY, or
- c) a single indication specifying START-OF-ACTIVITY; optionally followed by one or more consecutive indications specifying DATA; and concluded by a single indication specifying END-OF-ACTIVITY.

NOTE This last sequence is indicative of an incomplete or incorrect reception. Detection of an error in the sequence of received PhPDUs, or in the PhEs reception process, disables further Ph-DATA indications with a class parameter specifying DATA, END-OF-DATA, or END-OF-DATA-AND-ACTIVITY until after both the end of the current period of activity and the start of a subsequent period of activity have been reported by Ph-DATA indications specifying END-OF-ACTIVITY and START-OF-ACTIVITY, respectively.

In the first two cases, the DLE concatenates the received data and then attempts to parse it into a DLPDU followed by a concatenated FCS. In the last case the DLE discards all reported data and reports the event to DL-management.

5.5 Operational elements

5.5.1 Overview

The following times T are measured in bits. A time t in seconds (s) shall therefore be divided by the bit time t_{BIT} .

5.5.2 Bit time t_{BIT}

The bit time t_{BIT} is the time, which elapses during the transmission of one bit. It is equivalent to the reciprocal value of the data rate:

$$t_{BIT} = \frac{1}{\text{data} \cdot \text{rate}} \text{ [s bit}^{-1}\text{]} \quad (12)$$

5.5.3 Asynchronous transmission

5.5.3.1 Synchronization time (T_{SYN})

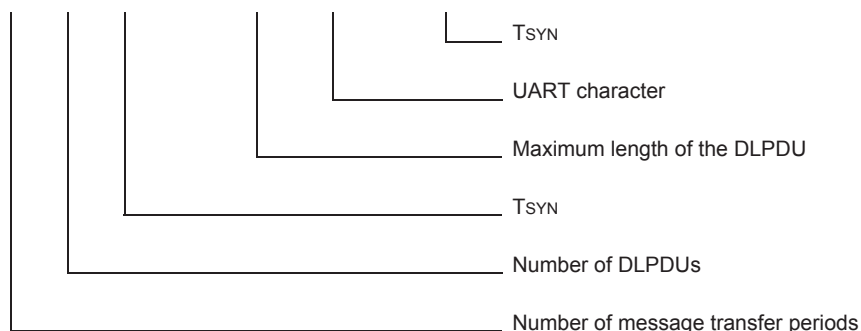
The synchronization time T_{SYN} is the minimum time interval during which each station shall receive idle state (idle = binary "1") from the transmission medium before it may accept the beginning of a send/request DLPDU or token DLPDU. The value of the synchronization time shall be set with:

$$T_{SYN} = 33 \text{ bit} \quad (13)$$

5.5.3.2 Synchronization interval time (T_{SYNI})

The synchronization interval time T_{SYNI} is the maximum allowed time interval between two consecutive synchronization times (T_{SYN}), in order to detect "permanent transmitters". The value of the synchronization interval time shall be set with:

$$T_{SYNI} = 2 \times (2 \times (33 \text{ bit} + 255 \times 11 \text{ bit})) + 33 \text{ bit} = 11\,385 \text{ bit} \quad (14)$$



This value regards two complete message transfer periods, each of which consists of two DLPDUs of maximum length and the related synchronization times. A transmission disturbance is permitted in one of those synchronization times.

5.5.3.3 Station delay time (T_{SDx})

The station delay time T_{SDx} is the period of time which may elapse between the transmission or receipt of a DLPDUs last bit until the transmission or receipt of a following DLPDUs first bit (with respect to the transmission medium, that is, including line receiver and transmitter). The following three station delays are defined:

- Station Delay of Initiator (station transmitting request or token DLPDU):
 T_{SDI}
- Minimum Station Delay of Responders (stations which acknowledge or respond):
 $\min T_{SDR}$
- Maximum Station Delay of Responders:
 $\max T_{SDR}$

5.5.3.4 Quiet time (T_{QUI})

When transposing the NRZ signals into a different signal coding, the transmitter fall time after switching off the transmitter (at the initiator) shall be taken into account if it is greater than T_{SDR}.

During this quiet time T_{QUI}, transmission and receipt of DLPDUs shall be disabled. This shall also be taken into account when using self-controlled repeaters, whose switching time shall be taken into consideration. The implementation shall ensure, that the following condition is fulfilled:

$$T_{QUI} < \min T_{SDR} \quad (15)$$

In order to fulfil this condition, it may be necessary to prolong min T_{SDR}.

5.5.3.5 Ready time (T_{RDY})

The ready time T_{RDY} is the time within which a master station shall be ready to receive an acknowledgement or response after transmitting a request. The implementation shall ensure, that the following condition is fulfilled:

$$T_{RDY} < \min T_{SDR} \quad (16)$$

In order to fulfil this condition it may be necessary to prolong min T_{SDR}.

When transposing NRZ signals into a different signal coding, the quiet time shall also be taken into consideration when switching off the transmitter. The receiver shall not be enabled before this time:

$$T_{QUI} < T_{RDY} \quad (17)$$

In order to fulfil this condition, it may be necessary to prolong T_{RDY} and thus min T_{SDR} accordingly.

5.5.3.6 Safety margin (T_{SM})

The following time interval is specified as safety margin T_{SM}:

$$T_{SM} = 2 \text{ bit} + 2 \times T_{SET} + T_{QUI} \quad (18)$$

T_{SET} is the set-up time, which expires from the occurrence of an event (for example, an interrupt on the last bit of a sent DLPDU or when synchronization time expires) until the necessary reaction is performed (for example, to start synchronization time or to enable the receiver).

5.5.3.7 Idle time (T_{IDx})

The idle time T_{IDx} is the time which expires at the initiator either after receipt of a DLPDU's last bit (measured at the line receiver) as idle = binary "1" on the transmission medium, until a new DLPDU's first bit is transmitted on the medium (including line transmitter) or between transmitting the last bit of a DLPDU which is not to be acknowledged and transmitting the first bit of the next DLPDU. The idle time shall be at least the synchronization time plus the safety margin T_{SM} (see Figure 4, Figure 5 and Figure 6 case a)).

$$T_{IDx} \geq T_{SYN} + T_{SM} \quad (19)$$

At high data rates (see Figure 4, case b) and c) and Figure 5 case b)) the synchronization time is very short, hence the station delays become significant and shall be taken into consideration.

Two idle times are distinguished. After an acknowledgement, response or token DLPDU the idle time shall be calculated as follows:

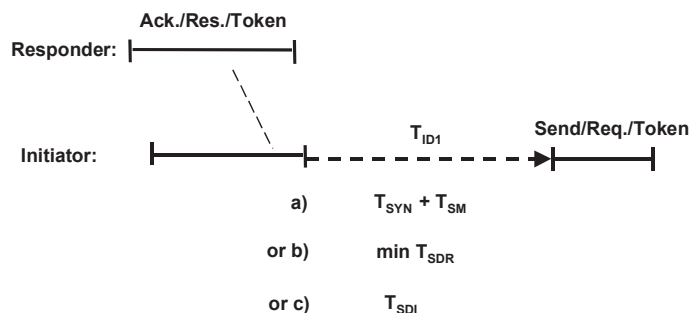


Figure 4 – Idle time T_{ID1}

$$T_{\text{ID1}} = \max ((T_{\text{SYN}} + T_{\text{SM}}), (\min T_{\text{SDR}}), T_{\text{SDI}}) \quad (20)$$

Care shall be taken that the time to update the LMS is not greater than T_{ID1} . This can be accomplished by prolonging T_{SET} or $\min T_{\text{SDR}}$. If the necessary prolongation cannot be reached with the range of value of T_{SET} , than the $\min T_{\text{SDR}}$ shall be made longer.

After a send DLPDU which is **not** to be acknowledged (SDN or CS), the idle time shall be calculated as shown in Figure 5 and equation (34).

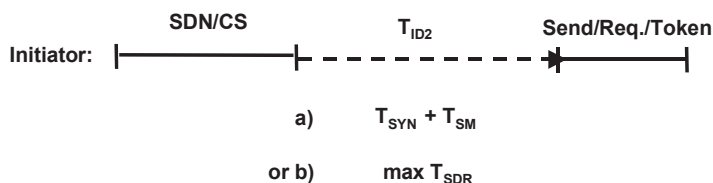


Figure 5 – Idle time T_{ID2} (SDN, CS)

$$T_{\text{ID2}} = \max ((T_{\text{SYN}} + T_{\text{SM}}), (\max T_{\text{SDR}})) \quad (21)$$

Also, after a response DLPDU (MSRD) the idle time shall be calculated as shown in Figure 6 and equation (34).

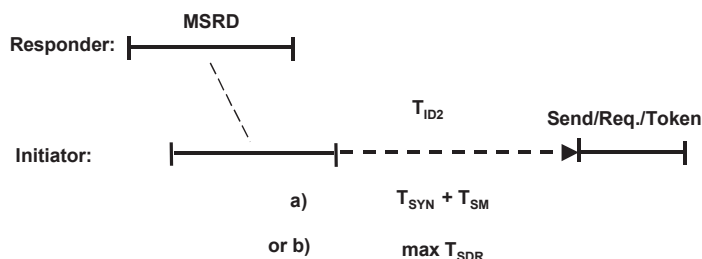


Figure 6 – Idle time T_{ID2} (MSRD)

5.5.3.8 Transmission delay time (T_{TD})

The transmission delay time T_{TD} is the maximum time, which elapses on the transmission medium between transmitter and receiver when a DLPDU is transmitted. When computing it, delay times of repeaters shall be considered, if necessary.

EXAMPLE Computing the transmission delay time: given a line length of 200 m without repeaters, T_{TD} is approximately 1 µs and thus at 500 kbit/s:

$$T_{TD} = (1\mu s \times 500 \text{ kbit/s}) = 0,5 \text{ bit.}$$

5.5.3.9 Slot time (T_{SL})

The slot time T_{SL} is the maximum time the initiator shall wait for the complete receipt of the first character (see 6.1.1, UART character, 1 UC = 11 bits) of the immediate acknowledgement or response DLPDU, after transmitting the last bit of a send/request DLPDU (including the line transmitter) (see Figure 7). Furthermore, T_{SL} is the maximum time the initiator waits for the token receiver's first UART character (1 UC) after transmitting a token DLPDU (see Figure 8). Theoretically, two slot times are distinguished. After a send/request DLPDU the slot time shall be calculated as follows:

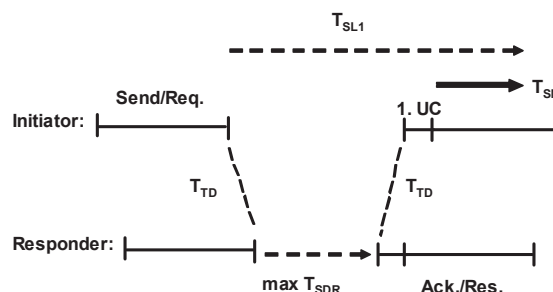


Figure 7 – Slot time T_{SL1}

$$T_{SL1} = 2 \times T_{TD} + \max T_{SDR} + 11 \text{ bit} + T_{SM} \quad (22)$$

After a token DLPDU the slot time shall be calculated as follows:

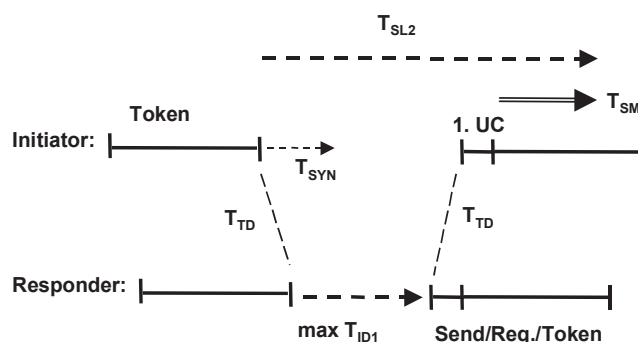


Figure 8 – Slot time T_{SL2}

$$T_{SL2} = 2 \times T_{TD} + \max T_{ID1} + 11 \text{ bit} + T_{SM} \quad (23)$$

In order to simplify the realization, only one slot time, the longer one, may be used in the system. This does not influence the system reaction time negatively, as the slot time is a pure monitoring time.

$$T_{SL} = \max(T_{SL1}, T_{SL2}) \quad (24)$$

5.5.3.10 Time-out time (T_{TO})

The time-out time T_{TO} serves to monitor the Master and slave stations' bus activity and idle time. Monitoring shall start either immediately after PON, in the "Listen-Token" or "Passive_Idle" state, or later after receiving the last bit of a DLPDU. It shall end after receiving the first bit of the following DLPDU. If the phase of no bus activity times out, the bus shall be regarded as inactive. (This is an error case, for example, due to a lost token DLPDU.) The time-out interval shall be set to:

$$T_{TO} = 6 \times T_{SL} + 2 \times n \times T_{SL} \quad (25)$$

For master stations: $n = \text{station address (0 to 126)}$

For slave stations: $n = 130$, independent of the station's address

The first term ensures that there is sufficient difference to the maximum permissible idle time between two DLPDUs. The second term ensures that not all master stations claim the token at the same moment after an error has occurred.

5.5.3.11 GAP update time (T_{GUD})

The GAP update time T_{GUD} serves for initializing GAP maintenance by the master station. After the first generation of the GAPL, update of the GAP image is cyclically initialized after every interval T_{GUD} . This initialization takes place at the next possible token receipt, if there is still token holding time available after the regular DLPDU transfer periods, or during later token holding phases. The GAP update time is a multiple of the target rotation time T_{TR} and shall be set to:

$$T_{GUD} = G \times T_{TR} \quad (\text{where } 1 \leq G \leq 100) \quad (26)$$

T_{TR} is the target rotation time (see 5.3.2.6).

5.5.3.12 Isochronous mode

5.5.3.12.1 Isochronous cycle time (T_{CT})

The isochronous cycle time T_{CT} serves to supervise the isochronous cycle. The first cycle starts by sending the SYNCH DLPDU after reception of the token DLPDU.

5.5.3.12.2 IsoM synchronization DLPDU time (T_{SYNCH})

The isochronous mode synchronization DLPDU time describes the time, which is needed to send the SYNCH DLPDU at the start of a new IsoM cycle. The value of the IsoM synchronization message time shall be set with:

$$T_{SYNCH} = 13 \times 11 \text{ bit} = 143 \text{ bit} \quad (27)$$

