

DIN EN 61158-4-11

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Ersatz für
DIN EN 61158-4-11:2013-01
Siehe Anwendungsbeginn

**Industrielle Kommunikationsnetze –
Feldbusse –
Teil 4-11: Protokollspezifikation des Data Link Layer
(Sicherheitsschicht) –
Typ 11-Elemente
(IEC 61158-4-11:2014);
Englische Fassung EN 61158-4-11:2014, nur auf CD-ROM**

Industrial communication networks –
Fieldbus specifications –
Part 4-11: Data-link layer protocol specification –
Type 11 elements
(IEC 61158-4-11:2014);
English version EN 61158-4-11:2014, only on CD-ROM

Réseaux de communication industriels –
Spécifications des bus de terrain –
Partie 4-11: Spécification du protocole de la couche liaison de données –
Éléments de type 11
(CEI 61158-4-11:2014);
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Anwendungsbereich

Anwendungsbereich für die von CENELEC am 2014-09-19 angenommene Europäische Norm als DIN-Norm ist 2015-09-01.

Für DIN EN 61158-4-11:2013-01 besteht eine Übergangsfrist bis 2017-09-19.

Nationales Vorwort

Vorausgegangener Norm-Entwurf: E DIN EN 61158-400:2013-08.

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

Die enthaltene IEC-Publikation wurde vom SC 65C „Industrial networks“ erarbeitet.

Das IEC-Komitee hat entschieden, dass der Inhalt dieser Publikation bis zu dem Datum (stability date) unverändert bleiben soll, das auf der IEC-Website unter „<http://webstore.iec.ch>“ zu dieser Publikation angegeben ist. Zu diesem Zeitpunkt wird entsprechend der Entscheidung des Komitees die Publikation

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- geändert.

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

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

Der Zusammenhang der zitierten Normen mit den entsprechenden Deutschen Normen 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 61158-4-11 veröffentlicht. Zu deren Abschnitt 1, der den Anwendungsbereich festlegt, und Abschnitt 3, der die Begriffe festlegt, wurde eine Übersetzung angefertigt und als Nationaler Anhang NA der vorliegenden Norm hinzugefügt. Für viele 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.

Einführung

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 61158 legen eine Anzahl von Feldbus-Protokolltypen fest. Die Reihe DIN EN 61158-4 legt das Protokoll des Data Link Layer für die einzelnen Typen fest.

Änderungen

Gegenüber DIN EN 61158-4-11:2013-01 wurden folgende Änderungen vorgenommen:

- a) zusätzliche Spezifikation für die Loop-Architekturen mit hoher Datenrate in 4.6.1, 4.6.4, 5.4.6, Abschnitt 6 und 7.2 hinzugefügt.

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 61158-4-11: 2008-09, 2013-01

Nationaler Anhang NA (informativ)

1 Anwendungsbereich^{N1)}

1.1 Allgemeines

Der Data Link Layer stellt grundlegende zeitkritische Kommunikation für den Datentransfer zwischen Geräten in einer Automatisierungsumgebung bereit.

Dieses Protokoll stellt Kommunikationsmöglichkeiten für alle teilnehmenden Data Link-Einheiten bereit

- a) in einem synchron gestarteten, zyklischen Ablauf, gemäß eines vordefinierten Ablaufplans, und
- b) in einer zyklischen oder azyklischen asynchronen Weise, wie für jede derartige Data Link-Einheit im jeweiligen Zyklus gefordert.

Demnach kann dieses Protokoll als eines charakterisiert werden, welches zyklischen und azyklischen asynchronen Zugriff bereitstellt, aber mit einem synchronen Neustart jedes Zyklus.

1.2 Spezifikationen

Diese Norm legt Folgendes fest:

- a) Prozeduren für zeitgerechten Datentransfer und Informationssteuerung von einer Data Link-Benutzereinheit zu einer gleichartigen Benutzereinheit sowie zwischen der Data Link-Einheit, welche den verteilten Data Link-Dienst-Anbieter bildet;
- b) Prozeduren zur Vergabe von Kommunikationsmöglichkeiten an alle teilnehmenden DL-Einheiten, sequenziell und in einer zyklischen Weise für deterministischen und synchronisierte Transfer bei zyklischen Intervallen bis zu einer Millisekunde;
- c) Prozeduren zur Vergabe von Kommunikationsmöglichkeiten, welche für zeitkritische Datentransfers zusammen mit nicht zeitkritischen Datentransfers ohne Beeinträchtigung des zeitkritischen Datentransfers erhältlich sind;
- d) Prozeduren zur Vergabe von zyklischen und azyklischen Kommunikationsmöglichkeiten für zeitkritischen Datentransfer mit priorisiertem Zugriff;
- e) Prozeduren zur Vergabe von Kommunikationsmöglichkeiten basierend auf ISO/IEC 8802-3 Medium Zugriffsteuerung, mit Maßnahmen zur Hinzufügung und Entfernung von Knoten während des normalen Betriebs;
- f) die Struktur der Feldbus-DLPDUs, welche verwendet werden für den Transfer von Daten und Informationssteuerung durch das Protokoll dieser Norm und ihre Darstellung als Physical Layer.

^{N1)} Die Nummerierung aus IEC 61158-4-11 wurde beibehalten.

1.3 Prozeduren

Die Prozeduren sind definiert in Form von

- a) den Interaktionen zwischen gleichartigen DL-Einheiten (DLEs) durch den Austausch der Feldbus DLPDUs,
- b) den Interaktionen zwischen einem DL-Dienst-(DLS-)Anbieter und einem DLS-Benutzer im selben System durch den Austausch von DLS-Primitiven,
- c) den Interaktionen zwischen einem DLS-Anbieter und einem Ph-Dienst-Anbieter im selben System durch den Austausch von Ph-Dienstprimitiven.

1.4 Anwendbarkeit

Diese Prozeduren sind auf Instanzen der Kommunikation zwischen Systemen anwendbar, welche die zeitkritischen Kommunikationsdienste innerhalb des Data Link Layer des OSI oder des Feldbusreferenzmodells unterstützen und die Fähigkeit erfordern, in einer offenen Systemverbundumgebung zu verbinden.

Profile stellen ein einfaches Multiattribut Hilfsmittel zur Zusammenfassung der Implementierungsfähigkeiten bereit und unterstützen dadurch die Anwendbarkeit für unterschiedliche zeitkritische Kommunikationsanforderungen.

1.5 Konformität

Diese Norm legt auch Konformitätsanforderungen für Systeme fest, die diese Prozeduren implementieren. Sie enthält jedoch keine Prüfungen, um die Konformität mit diesen Anforderungen nachzuweisen.

3.3 Begriffe

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe.

3.3.1

allgemeiner Speicher

(en: common memory)

virtueller allgemeiner Speicher für den Feldbus Typ 11, der von den teilnehmenden Typ 11-Feldbusknoten gemeinsam genutzt wird und vorrangig für die Echtzeit-Kommunikation des zeitkritischen zyklischen Datendienstes verwendet wird

3.3.2

Daten-DLPDU

(en: data DLPDU)

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

3.3.3

DLCEP-Adresse

(en: DLCEP-address)

DL-Adresse, die entweder

- a) einen DL-Verbindungsendpunkt von einem Peer oder
- b) einen DL-Verbindungsendpunkt von mehreren Peer-Publishern und implizit den entsprechenden Satz von Verbindungsendpunkten der DL-Subscriber kennzeichnet, wobei jeder DL-Verbindungsendpunkt innerhalb eines eindeutigen DLSAP vorhanden und einer entsprechenden eindeutigen DLSAP-Adresse zugeordnet ist

3.3.4

DL-Segment, Verbindungszweig, lokaler Verbindungszweig

(en: DL-segment, link, local link)

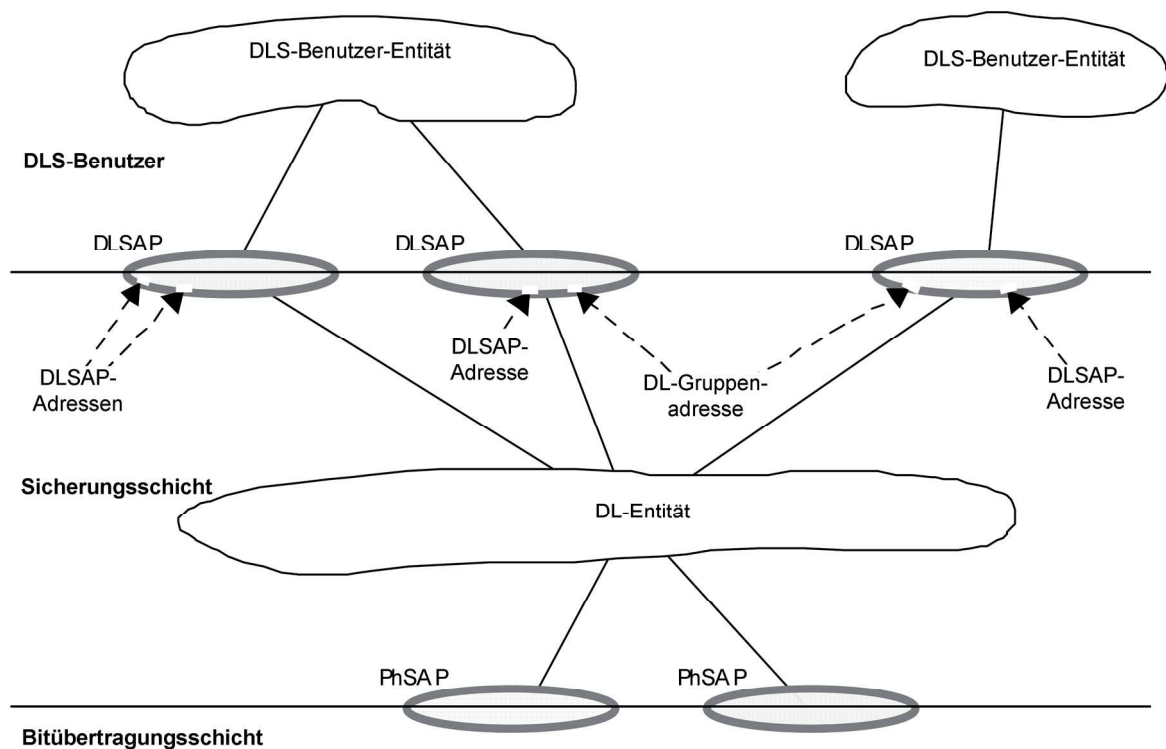
einzelnes DL-Subnetzwerk, in dem alle angeschlossenen DLEs direkt, d. h. ohne zwischengeschaltete DL-Weitergabe, kommunizieren können, solange alle an einem Kommunikationsvorgang teilnehmenden DLEs während der Dauer(n) der Kommunikationsversuche gleichzeitig auf das DL-Subnetzwerk reagieren können

3.3.5 DLSAP

(en: DLSAP)

eindeutiger Punkt, an dem eine einzelne DL-Entität einer einzelnen Entität auf höherer Schicht DL-Dienste bereitstellt

Anmerkung 1 zum Begriff: Diese Definition ist abgeleitet von ISO/IEC 7498-1 und wurde hier zum besseren Verständnis für die kritische Unterscheidung zwischen DLSAPs und ihren DL-Adressen wiederholt. (Siehe Bild 1.)



ANMERKUNG 1: DLSAPs und PhSAPs werden als Ellipsen dargestellt, die sich über die Grenze zweier benachbarter Schichten erstrecken.

ANMERKUNG 2: DL-Adressen werden als gekennzeichnete, kleine Lücken (Zugangspunkte) im DLL-Teil eines DLSAP dargestellt.

ANMERKUNG 3: Eine einzelne DL-Entität kann mehrere DLSAP-Adressen und DL-Gruppenadressen, die einem einzelnen DLSAP zugeordnet sind, besitzen.

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

3.3.6 DLSAP

(en: DLSAP)

eindeutiger Punkt, an dem eine einzelne DL-Entität einer einzelnen Entität auf höherer Schicht DL-Dienste bereitstellt

Anmerkung 1 zum Begriff: Diese Definition ist abgeleitet von ISO/IEC 7498-1 und wurde hier zum besseren Verständnis für die kritische Unterscheidung zwischen DLSAPs und ihren DL-Adressen wiederholt. (Siehe Bild 1.)

3.3.7

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 DLSAPs jeweils eines einzelnen DLS-Benutzers kennzeichnet

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

3.3.8

(individuelle) DLSAP-Adresse

(en: (individual) DLSAP-address)

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

Anmerkung 1 zum Begriff: Eine einzelne DL-Entität kann mehrere DLSAP-Adressen, die einem einzelnen DLSAP zugeordnet sind, besitzen.

3.3.9

erweiterter Verbindungszweig

(en: extended link)

DL-Subnetzwerk, das aus der maximalen Menge von Verbindungszweigen besteht, die über DL-Relais-Entitäten geschaltet werden können, wobei ein einziger DL-Namensraum (DL-Adressraum) gemeinsam genutzt wird; in diesem Subnetzwerk können alle angeschlossenen DL-Entitäten miteinander entweder direkt oder über eine oder mehrere der zwischengeschalteten DL-Relais-Entitäten kommunizieren

Anmerkung 1 zum Begriff: Ein erweiterter Verbindungszweig besteht möglicherweise aus nur einem einzelnen Verbindungszweig.

3.3.10

FCS-Fehler

(en: FCS error)

Fehler, der auftritt, wenn der berechnete Wert der Blockprüfzeichenfolge nach Empfang aller Oktette in einer DLPDU nicht mit dem erwarteten Rest übereinstimmt

3.3.11

Rahmen

(en: frame)

umgangssprachliches Synonym für DLPDU

3.3.12

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-Entität kann mehrere DL-Gruppenadressen, die einem einzelnen DLSAP zugeordnet sind, besitzen.

Anmerkung 2 zum Begriff: Eine einzelne DL-Entität kann auch eine einzelne DL-Gruppenadresse, die mehr als einem DLSAP zugeordnet ist, besitzen.

3.3.13

zyklische Hochgeschwindigkeitsdaten

(en: high-speed cyclic data)

Daten, die mithilfe von zyklischer Hochgeschwindigkeits-Datenübertragung übermittelt werden

3.3.14**zyklische Hochgeschwindigkeits-Datenübertragung**

(en: high-speed cyclic data transmission)

höchste Priorität des zeitkritischen zyklischen Datendienstes

3.3.15**implizites Token**

(en: implicit token)

Mechanismus, der das Recht zur Übertragung steuert

Anmerkung 1 zum Begriff: Über das Medium wird keine eigentliche Token-Nachricht übertragen. Jeder Knoten verfolgt den Knoten, von dem er annimmt, dass dieser derzeit das Recht zur Übertragung hat. Das Recht zur Übertragung wird von Knoten zu Knoten durch Aufzeichnen des Knotens, der zuletzt übertragen hat, weitergegeben. Damit ein fehlender Knoten im Durchlauf übersprungen werden kann, wird eine Schlitzzeit verwendet.

3.3.16**zyklische Niedriggeschwindigkeitsdaten**

(en: low-speed cyclic data)

Daten, die mithilfe von zyklischer Niedriggeschwindigkeits-Datenübertragung übermittelt werden

3.3.17**zyklische Niedriggeschwindigkeits-Datenübertragung**

(en: low-speed cyclic data transmission)

niedrigste Priorität des zeitkritischen zyklischen Datendienstes

3.3.18**zyklische Mittelgeschwindigkeitsdaten**

(en: medium-speed cyclic data)

Daten, die mithilfe von zyklischer Mittelgeschwindigkeits-Datenübertragung übermittelt werden

3.3.19**zyklische Mittelgeschwindigkeits-Datenübertragung**

(en: medium-speed cyclic data transmission)

zweithöchste Priorität des zeitkritischen zyklischen Datendienstes

3.3.20**Multi-Peer-DLC**

(en: multi-peer DLC)

zentralisierte DL-Verbindung mit mehreren Endpunkten, die eine DL-Duplex-Übertragung zwischen einem einzelnen definierten DLS-Benutzer, auch bekannt als Publisher oder veröffentlichender DLS-Benutzer, und einer Menge von Peers, die jedoch nicht definierten DLS-Benutzern entsprechen, die in ihrer Gesamtheit als Subscriber oder abonnierende DLS-Benutzer bekannt sind, anbietet

Anmerkung 1 zum Begriff: Der veröffentlichende DLS-Benutzer kann Daten an die abonnierenden DLS-Benutzer als Gruppe (jedoch nicht einzeln) senden, und die abonnierenden DLS-Benutzer können Daten an den veröffentlichenden DLS-Benutzer (jedoch sich nicht gegenseitig) senden.

3.3.21**Mehrpunktverbindung**

(en: multipoint connection)

Verbindung von einem Knoten zu vielen Knoten

Anmerkung 1 zum Begriff: Durch Mehrpunktverbindungen kann der Datentransfer von einem einzelnen Publisher von vielen Subscriber-Knoten empfangen werden.

3.3.22**Knoten**

(en: node)

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

3.3.23

DL-Knotenadresse

(en: node DL-address)

DL-Adresse, welche die (einzelne) DL-Entität kennzeichnet, die einem einzelnen Knoten auf einem spezifischen lokalen Verbindungszweig zugeordnet ist

3.3.24

Knoten-ID

(en: node-id)

primäre Kennung aus zwei Oktetten für die DLE auf dem lokalen Verbindungszweig, deren Werte beschränkt sind

Anmerkung 1 zum Begriff: Ein zulässiger Wert liegt zwischen 1 und 255. Der Wert „0“ wird speziell für den SYN-Knoten, der den SYN-Rahmen ausgibt, verwendet.

3.3.25

empfangender DLS-Benutzer

(en: receiving DLS-user)

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

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

3.3.26

sendender DLS-Benutzer

(en: sending DLS-user)

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

3.3.27

Schlitzzeit

(en: slot-time)

512-Bit-Zeit bzw. 4 096-Bit-Zeit des physischen Signalisierungssymbols für eine Datengeschwindigkeit von 100 Mbps bzw. 1 000 Mbps, festgelegt in ISO/IEC 8802-3:2000, Abschnitt 29

3.3.28

sporadischer Nachrichtendatendienst

(en: sporadic message data service)

nicht-periodischer Nachrichtentransfer, der auf Anforderung eines DLS-Benutzers zur Übertragung einer oder mehrerer Nachrichten sporadisch auftritt, der normale Ethernet-Nachrichtenrahmen nach ISO/IEC 8802-3 wird mithilfe dieses Nachrichtentransfers übertragen

3.3.29

SYN-Knoten

(en: SYN node)

Knoten, der den SYN-Rahmen überträgt

3.3.30

zeitkritischer zyklischer Datendienst

(en: time-critical cyclic data service)

zyklischer Datentransfer mit drei gleichzeitigen Stufen der Datenübertragung, wobei jede Datenübertragungsstufe der Datenpriorität und der Datenübertragungsdauer für eine Echtzeit-Übertragung entspricht und die Datenübertragungsdauer sowie das Gesamtdatenvolumen für jede Stufe in der Entwurfsphase und entsprechend den Anwendungsanforderungen festgelegt werden kann

3.3.31

Token

(en: token)

Recht zur Übertragung auf dem lokalen Verbindungszweig

English Version

**Industrial communication networks – Fieldbus specifications -
Part 4-11: Data-link layer protocol specification – Type 11
elements
(IEC 61158-4-11:2014)**

Réseaux de communication industriels – Spécifications des
bus de terrain – Partie 4-11: Spécification du protocole de la
couche liaison de données – Éléments de type 11
(CEI 61158-4-11:2014)

Industrielle Kommunikationsnetze – Feldbusse - Teil 4-11:
Protokollspezifikation des Data Link Layer
(Sicherheitsschicht) – Typ 11- Elemente
(IEC 61158-4-11:2014)

This European Standard was approved by CENELEC on 2014-09-19. 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

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Foreword

The text of document 65C/762/FDIS, future edition 3 of IEC 61158-4-11, prepared by SC 65C "Industrial networks" of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61158-4-11:2014.

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

This document supersedes EN 61158-4-11:2012.

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Endorsement notice

The text of the International Standard IEC 61158-4-11:2014 was approved by CENELEC as a European Standard without any modification.

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

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

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

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

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

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

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning Type 11 elements and possibly other types given in 4.2, 4.4, 4.5, 5.4, 6.2 to 6.10, 7.1 and 7.2 as follows:

AU 2007320662(B2) [TO] Double ring network system, communication control method thereof, transmission station, and communication control program of double ring network system

ZL 200780042584.7 [TO] Double ring network system, communication control method thereof, transmission station, and communication control program of double ring network system

JP 4991254(B2) [TO] Control method for double-ring network, initializing method for double-ring network, transmission station of double-ring network, restructuring method for abnormality occurrence of double-ring network, network system, control method for network system, transmission station, and program of transmission station

KR 101149837(B1) [TO] Double ring network system, communication control method thereof, transmission station, and communication control program of double ring network system

RU 2420899(C2) [TO] Double-ring network system and method of controlling communication in said network, transmission station and programme for transmission stations

US 8411559(B2) [TO] Double ring network system and communication control method thereof, and transmission station, and program for transmission stations

EP 2093942(A1) [TO] Double ring network system, communication control method thereof, transmission station, and communication control program of double ring network system

US 6711131(B1) [TO] Data transmitting apparatus, network interface apparatus, and data transmitting system

JP 3461954(B2) [TO] Data transmitter

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-11: Data-link layer protocol specification – Type 11 elements

1 Scope

1.1 General

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

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

- a) in a synchronously-starting cyclic manner, according to a pre-established schedule, and
- b) in a cyclic or acyclic asynchronous manner, as requested each cycle by each of those data-link entities.

Thus this protocol can be characterized as one which provides cyclic and acyclic access asynchronously but with a synchronous restart of each cycle.

1.2 Specifications

This standard specifies

- a) procedures for the timely transfer of data and control information from one data-link user entity to a peer user entity, and among the data-link entities forming the distributed data-link service provider;
- b) procedures for giving communications opportunities to all participating DL-entities, sequentially and in a cyclic manner for deterministic and synchronized transfer at cyclic intervals up to one millisecond;
- c) procedures for giving communication opportunities available for time-critical data transmission together with non-time-critical data transmission without prejudice to the time-critical data transmission;
- d) procedures for giving cyclic and acyclic communication opportunities for time-critical data transmission with prioritized access;
- e) procedures for giving communication opportunities based on standard ISO/IEC 8802-3 medium access control, with provisions for nodes to be added or removed during normal operation;
- f) the structure of the fieldbus DLPDUs used for the transfer of data and control information by the protocol of this standard, and their representation as physical interface data units.

1.3 Procedures

The procedures are defined in terms of

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

1.4 Applicability

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

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

1.5 Conformance

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

2 Normative references

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

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

IEC 61158-3-11:2007, *Industrial communication networks – Fieldbus specifications – Part 3-11: Data-link layer service definition – Type 11 elements*

IEC 61158-5-11:2007, *Industrial communication networks – Fieldbus specifications – Part 5-11: Application layer service definition – Type 11 elements*

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

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

ISO/IEC 8802-3:2000, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

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

3 Terms, definitions, symbols and abbreviations

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

3.1 Reference model terms and definitions

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

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

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 7498-1]
3.1.37	(N)-interface-data-unit DL-service-data-unit (N=2) Ph-interface-data-unit (N=1)	[ISO/IEC 7498-1]
3.1.38	(N)-layer DL-layer (N=2) Ph-layer (N=1)	[ISO/IEC 7498-1]
3.1.39	(N)-service DL-service (N=2) Ph-service (N=1)	[ISO/IEC 7498-1]
3.1.40	(N)-service-access-point DL-service-access-point (N=2) Ph-service-access-point (N=1)	[ISO/IEC 7498-1]
3.1.41	(N)-service-access-point-address DL-service-access-point-address (N=2) Ph-service-access-point-address (N=1)	[ISO/IEC 7498-1]
3.1.42	peer-entities	[ISO/IEC 7498-1]
3.1.43	Ph-interface-control-information	[ISO/IEC 7498-1]
3.1.44	Ph-interface-data	[ISO/IEC 7498-1]
3.1.45	primitive name	[ISO/IEC 7498-3]
3.1.46	reassembling	[ISO/IEC 7498-1]
3.1.47	recombining	[ISO/IEC 7498-1]
3.1.48	reset	[ISO/IEC 7498-1]
3.1.49	responding-DL-address	[ISO/IEC 7498-3]
3.1.50	routing	[ISO/IEC 7498-1]
3.1.51	segmenting	[ISO/IEC 7498-1]
3.1.52	sequencing	[ISO/IEC 7498-1]
3.1.53	splitting	[ISO/IEC 7498-1]
3.1.54	synonymous name	[ISO/IEC 7498-3]
3.1.55	systems-management	[ISO/IEC 7498-1]
3.2	Service convention terms and definitions	

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

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

3.3 Terms and definitions

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

3.3.1 common memory

virtual common memory over Type 11 fieldbus, which is shared by participating Type 11 fieldbus nodes and is primarily used for real-time communications by the time-critical cyclic data service

3.3.2

data DLPDU

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

3.3.3

DLCEP-address

DL-address which designates either

- a) one peer DL-connection-end-point, or
- b) one multi-peer publisher DL-connection-end-point and implicitly the corresponding set of subscriber DL-connection-end-points where each DL-connection-end-point exists within a distinct DLSAP and is associated with a corresponding distinct DLSAP-address

3.3.4

DL-segment, link, local link

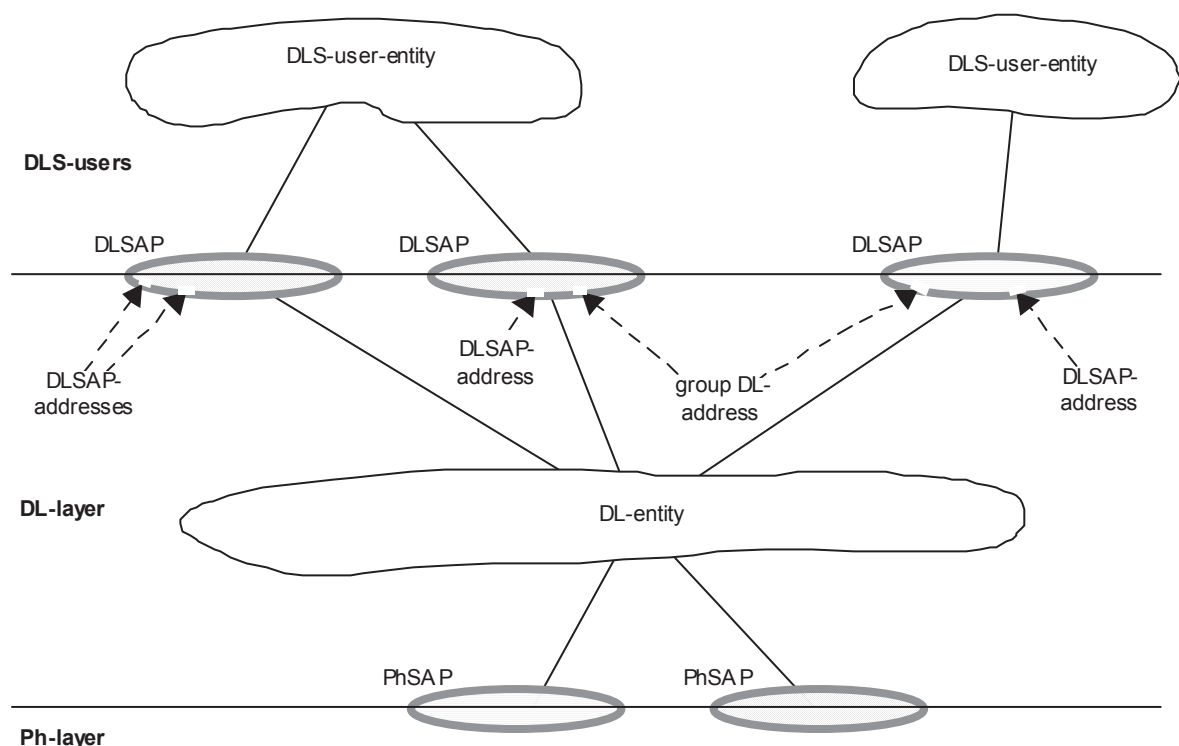
single DL-subnetwork in which any of the connected DLEs may communicate directly, without any intervening DL-relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the period(s) of attempted communication

3.3.5

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 can have multiple DLSAP-addresses and group DL-addresses associated with a single DLSAP.

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

3.3.6 DLSAP

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

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

3.3.7 DL(SAP)-address

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

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

3.3.8 (individual) DLSAP-address

DL-address that designates only one DLSAP within the extended link

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

3.3.9 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 can be composed of just a single link.

3.3.10 FCS error

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

3.3.11 frame

denigrated synonym for DLPDU

3.3.12 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.

3.3.13 high-speed cyclic data

data conveyed by means of high-speed cyclic data transmission

3.3.14 high-speed cyclic data transmission

highest priority of time-critical cyclic data service

3.3.15 implicit token

mechanism that governs the right to transmit

Note 1 to entry: No actual token message is transmitted on the medium. Each node keeps track of the node that it believes currently holds the right to transmit. The right to transmit is passed from node to node by keeping the node that last transmitted. A slot time is used to allow a missing node to be skipped in the rotation.

3.3.16

low-speed cyclic data

data conveyed by means of low-speed cyclic data transmission

3.3.17

low-speed cyclic data transmission

lowest priority of time-critical cyclic data service

3.3.18

medium-speed cyclic data

data conveyed by means of medium-speed cyclic data transmission

3.3.19

medium-speed cyclic data transmission

second-highest priority of time-critical cyclic data service

3.3.20

multi-peer DLC

centralized multi-end-point DL-connection offering DL-duplex-transmission between a single distinguished DLS-user known as the publisher or publishing DLS-user, and a set of peer but undistinguished DLS-users known collectively as the subscribers or subscribing DLS-users

Note 1 to entry: The publishing DLS-user can send to the subscribing DLS-users as a group (but not individually), and the subscribing DLS-users can send to the publishing DLS-user (but not to each other).

3.3.21

multipoint connection

connection from one node to many nodes

Note 1 to entry: Multipoint connections allows data transfer from a single publisher to be received by many subscriber nodes.

3.3.22

node

single DL-entity as it appears on one local link

3.3.23

node DL-address

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

3.3.24

node-id

two-octet primary identifier for the DLE on the local link, whose values are constrained

Note 1 to entry: A permissible value is from 1 to 255. A value 0 is specifically used for SYN node, which emits SYN frame.

3.3.25

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.

3.3.26

sending DLS-user

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

3.3.27

slot-time

512-bit time and 4 096-bit time of the physical signaling symbol for the data rate of 100 Mbps and 1 000 Mbps respectively specified in the ISO/IEC 8802-3:2000, Clause 29

3.3.28

sporadic message data service

aperiodic message transfer which sporadically occurs upon DLS-user requesting one or more message to transfer, and regular ISO/IEC 8802-3 Ethernet message frame is transferred by means of this message transfer

3.3.29

SYN node

node transmitting SYN frame

3.3.30

time-critical cyclic data service

cyclic data transfer with three levels of data transmission at the same time, of which each data transmission level is according to the data priority and the data transmission period for real-time delivery, and of which data transmission period and total data volume for each level can be specified in designing phase and on application needs

3.3.31

token

right to transmit on the local link

3.4 Symbols and abbreviations

ACM	Access control machine
CLM	Claim frame
CMP	Transmission complete frame
CTRC	Cyclic-transmission TX/RX control
COM	Command frame
DT	Cyclic data frame
CW	Control word (as parameter of SYN DLPDU)
DT-CMP	DT with transmission complete frame
FC	Frame control field
LL	Live list (as parameter of SYN DLPDU)
Mbps	Million bits per second
PhIDU	Ph-interface-data-unit
PM	Periodic mode (as parameter of SYN DLPDU)

PN	Transmission permits node number (as parameter of SYN DLPDU)
Pri	Priority field
RAS	RAS frame
REC	In-ring request frame
RMC	Redundancy medium control
RMSEL	Redundant medium selection
RN	Recipient node number
SN	Source node number field
ST	Slot time (as parameter of SYN DLPDU)
SYN	Synchronization frame
Th	High-speed transmission period (as transmission period)
Tm	Medium-speed transmission period (as transmission period)
Ts	Sporadic-speed transmission period (as transmission period)
TI	Low-speed transmission period (as transmission period)

4 Overview of the DL-protocol

4.1 General

This standard meets the industrial automation market objective of providing predictable time deterministic and reliable time-critical data transfer and means, which allow co-existence with non-time-critical data transfer over the ISO/IEC 8802-3 series communications media, for support of cooperation and synchronization between automation processes on field devices in a real-time application system. The term “time-critical” is used to represent the presence of a time-window, within which one or more specified actions are required to be completed with some defined level of certainty.

4.1.1 Field of applications

In industrial control systems, several kinds of field devices such as Drives, Sensors and Actuators, Programmable controllers, Distributed Control Systems and Human Machine Interface devices are required to be connected with control networks. The process control data and the state data is transferred among these field devices in the system and the communications between these field devices requires simplicity in application programming and to be executed with adequate response time. In most industrial automation systems such as food, water, sewage, paper and steel, including a rolling mill, the control network is required to provide time-critical response capability for their application, as required in ISO/TR 13283 for time-critical communications architectures.

Plant production may be compromised due to errors, which could be introduced to the control system if the network does not provide a time-critical response. Therefore, the following characteristics are required for a time-critical control network:

- deterministic response time between the control device nodes;
- ability to share process data seamlessly across the control system.

This protocol is applicable to such an industrial automation environment, in which time-critical communications is primarily required. The term “time-critical” is used to represent the presence of a time window, within which one or more specified actions are required to be completed with some defined level of certainty. Failure to complete specified actions within the time-window risks failure of the applications requesting the actions, with attendant risk to equipment, plant and possibly human life.

4.2 Overview of the medium access control

The Type 11 fieldbus has a deterministic medium access control in order to avoid collisions that occur when a number of the nodes send data frames simultaneously, and to provide the opportunity of sending data to each node in a sequential order and within a predetermined time period. Figure 2 shows the basic principle of medium access control of the Type 11 fieldbus.

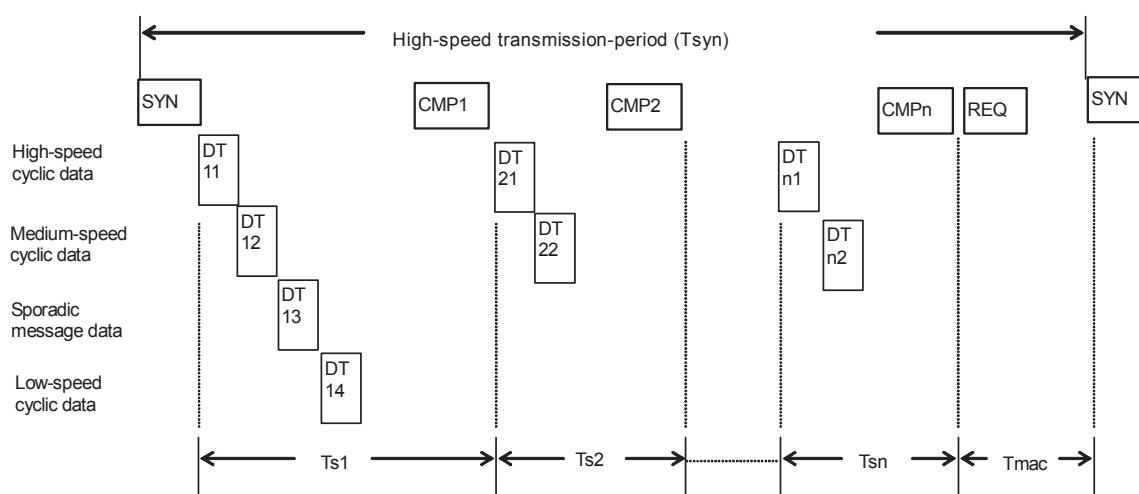


Figure 2 – Basic principle of medium access control

At the start time of every high-speed-transmission-period (T_{syn}), the SYN frame is broadcasted to all nodes. Receiving the SYN frame, the node with sequential number 1 starts sending its data frames, and after that broadcasts its CMP frame in order to indicate the completion of its data frames transmission. The Nth node can send out its data frames after receiving the CMP frame from the (N-1) node. After all the nodes send their data frames, the time period to solicit new nodes begins. The REQ frame is used for a new node requesting inclusion to the Type 11 fieldbus network. The sequential number is assigned to a new node at the time approval to join is granted.

Each node can hold the transmission right for a preset time and shall send its CMP frame to transfer the transmission right to the next node within the preset time. The data to be sent and the data to be held over are determined by priority.

Transmission includes Time-critical cyclic data and sporadic Ethernet message transmission. Cyclic data transmission is divided into High-, Medium- and Low-speed data transmission. Each node sends the High-speed cyclic data frames on each occasion when it obtains the transmission right. The data of lower priorities, that is the Medium-speed cyclic data, the sporadic Ethernet message data and the Low-speed cyclic data respectively, is sent or not sent depending on the circumstances. The holding time of the transmission right of each node is determined by the settings of the High-speed cyclic, the Medium-speed cyclic, the sporadic Ethernet message and the Low-speed cyclic data transmission periods and by the volume of transmission data for each node. After sending all the High-speed cyclic data, the node sends the Medium-speed cyclic data. If the holding time of the transmission right ends during sending the Medium-speed cyclic data, the transmission of the

Medium-speed cyclic data is interrupted, and the CMP frame is sent. The n^{th} node obtains the transmission right again during the next High-speed data transmission period, during which time all the High-speed cyclic data and the remainder of the previous Medium-speed cyclic data is sent. Tmac is the period for a new node sending out REQ frame to enter the network.

Two kinds of the architecture, that are the star- and the loop-architecture, are specified in 4.4. Particularly in the loop-architecture the order of priority for the sporadic Ethernet message data and the Low-speed cyclic data changes with the capability for sending out the Low-speed cyclic data in the 100 Mbps and the 1 000 Mbps operation. The order of priority for the sporadic Ethernet message data is of the lowest, and the Low-speed cyclic data is not capable in the 100 Mbps operation.

4.3 Service assumed from the PhL

4.3.1 General

Subclause 4.3 describes the assumed Physical Service (PhS) and the constraints on use by the Type 11 DLE. The Physical Service is assumed to provide the following service primitives specified by ISO/IEC 8802-3:2000, Clause 6.

4.3.2 Assumed primitives of PhS

The PhS is assumed to provide the following two categories of primitives to the Type 11 DL-protocol.

- service primitives for transmitting and receiving frames to / from other peer DLEs;
- service primitives that provide information needed by the local DLE to perform the media access functions.

The assumed primitives of PhS are grouped into these two categories:

- Transfer of Data to all other peer DLE:
 - PLS_DATA request;
 - PLS_DATA indication;
- Media access management by local DLE:
 - PLS_CARRIER indication;
 - PLS_SIGNAL indication;
 - PLS_DATA_VALID indication.

The interaction of the PhS primitives to the DLE is shown in Figure 3.

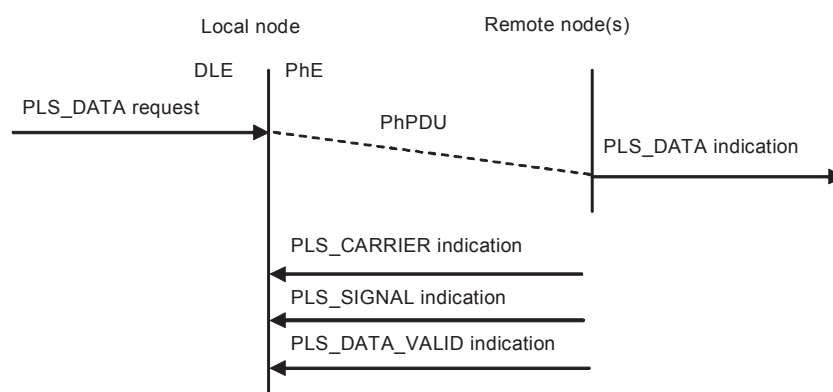


Figure 3 – Interaction of PhS primitives to DLE

4.4 DLL architecture

4.4.1 Overview

The Type 11 fieldbus DLL is modeled as a combination of control components of Access Control Machine (ACM), Cyclic transmission TX/RX Control (CTRC), Sporadic TX/RX Control (STRC), Redundancy Medium Control (RMC), Serializer, Deserializer and DLL management interface.

The Access Control Machine as the primary control component provides the function for deterministic medium access control cooperating with the Cyclic-transmission TX/RX Control, the Sporadic TX/RX Control and the Redundancy Medium Control for reliable and efficient support of higher-level connection-mode and connectionless data transfer services. Specifically the Access Control Machine has the primary responsibility for

- a) assuring that the local node detects and fully utilizes its assigned access time period;
- b) assuring that the local node does not interfere with the transmissions of other nodes, especially of the node transmitting the SYN frame;
- c) detecting network disruption, and initiating the SYN frame transmission for restoration of the network disruption from after prescribed time duration in which the SYN frame is not heard;
- d) assuring a new node adding to and removing from the network.

The DLL management interface provides DLL management functions. PhL framing and delimiters are managed by DLL functions for serializing and deserializing M_symbol requests and indications.

4.4.2 Star-architecture

The Data-link layer is comprised of the components listed in Table 1. The internal arrangement of these components, and their interfaces, are shown in Figure 4. The arrowheads illustrate the primary direction of flow of data and control.

Table 1 – Data-link layer components of star-architecture

Components	Description
Access control machine (ACM)	Deterministic medium access control and scheduling the opportunities to sending out the DLPDUs, control for adding and removing nodes, restoration from disruption. Assembles and transmits the DLPDUs to the TX framer through the RMC, receives and disassembles the DLPDUs with the control information from the RMC, and determines the timing and duration of the transmissions. Signals the RMC to sending out the DLPDUs for control and diagnosis of the Type 11 fieldbus. Buffers and dispatches in time the DLPDUs received between the DLS-user and the RMC
Cyclic transmission TX/RX control (CTRC)	Buffers and dispatches in time DLSDU received for the time-critical cyclic data transfer between the DLS-user and the ACM
Sporadic TX/RX control (STRC)	Buffers and dispatches in time DLSDU received for the Sporadic message data between DLS-user and the ACM
Redundancy medium control (RMC)	Receives the DLPDUs from the ACM and breaks them down into octet symbol requests to the Octet serializer, assembles received octets from the Octet deserializer into DLPDUs and submits them to the ACM. Selects one of two outputs of the Octet deserializers through the RX framers for medium redundancy
TX/RX framer	Receives the octet symbols from the RMC, detects and indicates the start timing of a DLPDU to the Octet serializer, passes received octets from the Octet deserializer and indicates the start timing of a DLPDU to the RMC
Octet serializer	Receives octet symbols, encodes and serializes them, and sends them as M_symbols to the PhL. It is also responsible for generating the FCS
Octet deserializer	Receives M_symbols from the PhL, converts M_symbols into octets and sends them to the RX framer. It is also responsible for checking the FCS
DLL management interface	Holds the station management variables that belong to the DLL, and manages synchronized changes of the link parameters

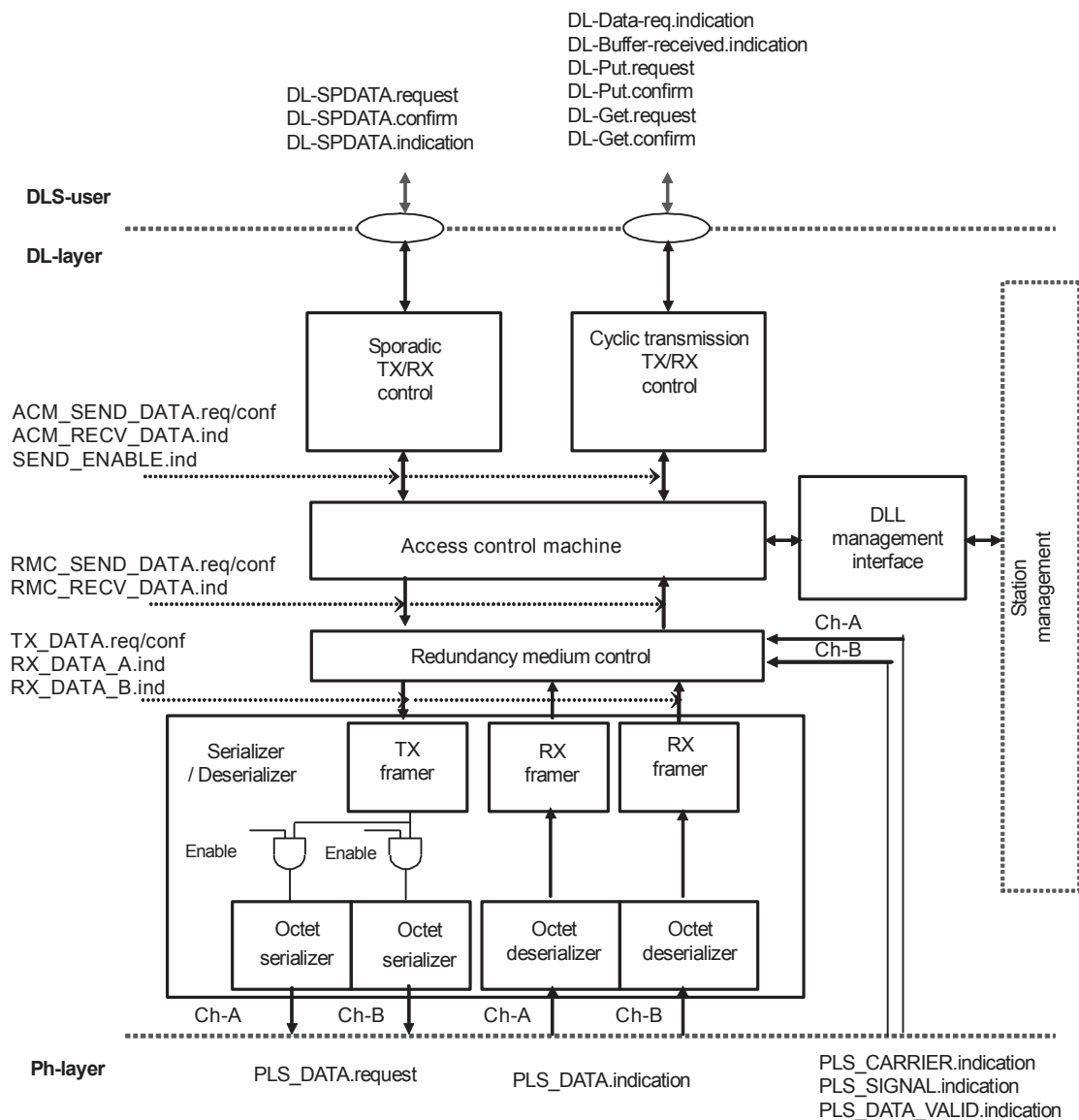


Figure 4 – Data-link layer internal architecture of star-architecture

4.4.3 Loop-architecture

The Data-link layer is comprised of the components listed in Table 2. The internal arrangement of these components, and their interfaces, are shown in Figure 5. The arrowheads illustrate the primary direction of flow of data and control.

Table 2 – Data-link layer components of loop-architecture

Components	Description
Access control machine (ACM)	Deterministic medium access control and scheduling the opportunities to sending out the DLPDUs, control for adding and removing nodes, restoration from disruption. Assembles and transmits the DLPDUs to the TX framer through the RMC, receives and disassembles the DLPDUs with the control information from the RMC, and determines the timing and duration of the transmissions. Signals the RMC to sending out the DLPDUs for control and diagnosis of the Type 11 fieldbus. Buffers and dispatches in time the DLPDUs received between the DLS-user and the RMC
Cyclic transmission TX/RX control (CTRC)	Buffers and dispatches in time DLSDU received for the time-critical cyclic data transfer between the DLS-user and the ACM
Sporadic TX/RX control (STRC)	Buffers and dispatches in time DLSDU received for the Sporadic message data between DLS-user and the ACM
Redundancy medium control (RMC)	Receives the DLPDUs from the ACM and breaks them down into the octet-symbol requests to the TX-framer, assembles received-octets from the RX-framers into the DLPDUs, selects one of two outputs from the RX-framers and submits them to the ACM. Receives the signal from the ACM and activates the transmission of the DLPDU frames for control and diagnosis of the Type 11 fieldbus
TX/RX framer	TX framer receives the octet-symbols from the RMC, detects and indicates the start timing of a DLPDU to the Octet-serializer, forwards received-octets from the Octet-deserializer connected to a Ring-port to other Octet-serializer connected to other Ring-port. RX framer passes received-octets from the Octet-deserializer and indicates the start-delimiter of a DLPDU to the RMC
Octet serializer	Receives octet symbols, encodes and serializes them, and sends them as M_symbols to the PhL. It is also responsible for generating the FCS
Octet deserializer	Receives M_symbols from the PhL, converts M_symbols into octets and sends them to the RX framer and the TX framer. It is also responsible for checking the FCS
DLL management interface	Holds the station management variables that belong to the DLL, and manages synchronized changes of the link parameters

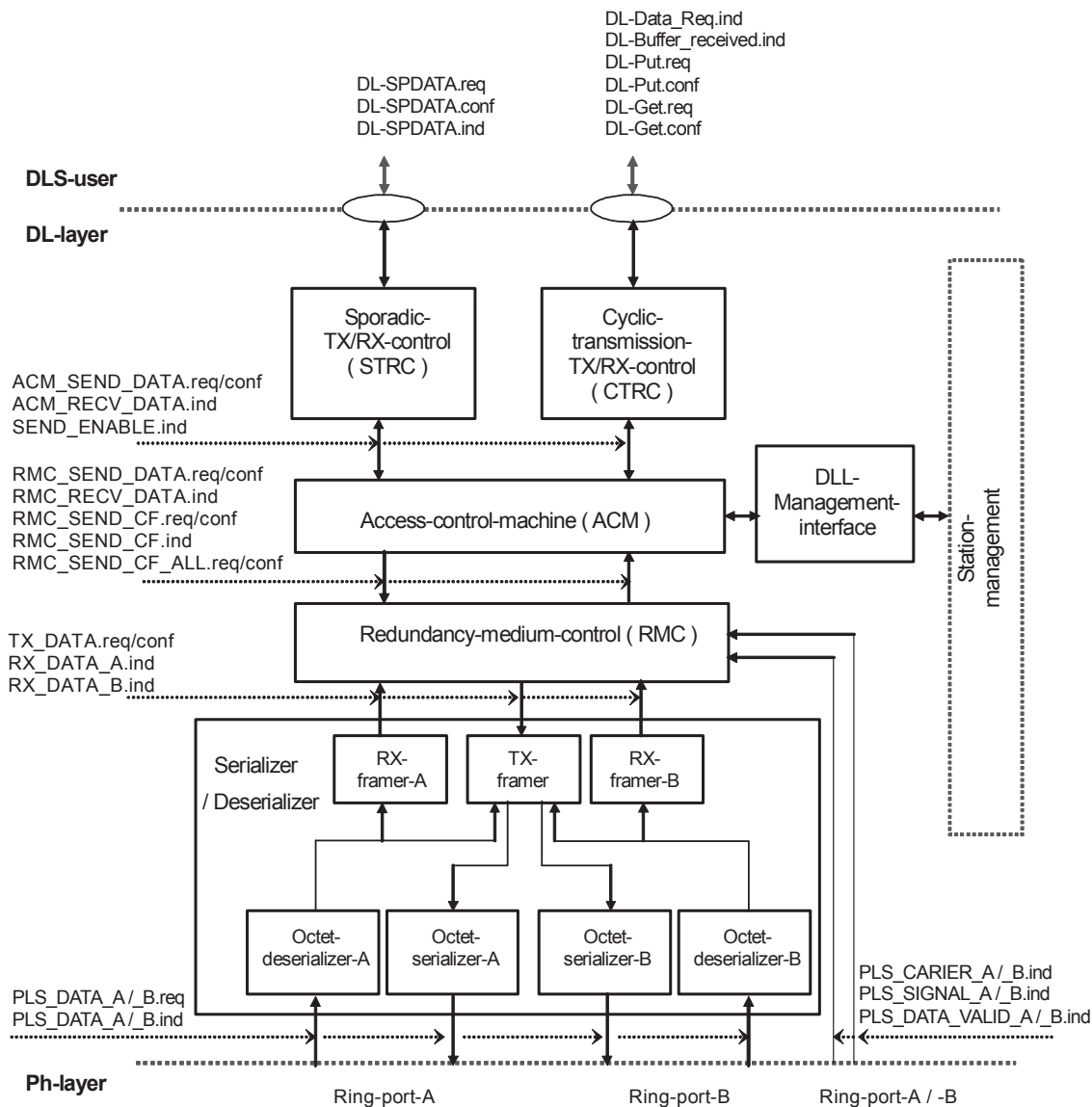


Figure 5 – Data-link layer internal architecture of loop-architecture

4.5 Access control machine and schedule support functions

The ACM functions schedule all communications between the DLEs participating in the Type 11 fieldbus, and the timing of this communications is controlled as to

- fulfill the specific medium access control to give all the DLEs the opportunities to send out two kinds of class of Time-critical cyclic data and Sporadic message data in timely, prioritized and deterministic fashion, and to detect network disruption and to initiate the restoration in appropriate time, further to add and remove nodes on line;
- provide multiple levels of Time-critical data transfer opportunities of sending data to node in sequential order and within each pre-specified time period, and that the data transfer of each level is performed within the pre-specified time duration (token holding time) and whether the data transfer of lower levels to be carried out or to be held over to later cyclic time period depends on the level and the occasion though the top level of the data transfer is always carried out at every occasion; on the other hand the whole volume of the data transfer of lower levels is transferred within each pre-specified time period;

- c) provide sporadic message data transfer opportunities of sending out to node that the request to transfer is happened sporadically by the DLS-user, and the data transfer is performed in pre-specified time period of the corresponding level of priority and is based on regular ISO/IEC 8802-3 applications.

Accurate scheduling timing is very important to support many control and data collection tasks in the applications domain of this protocol.

4.6 Local parameters, variables, counters, timers and queues

4.6.1 Overview

4.6.1.1 General

This standard uses DLS-user request parameters $P(\dots)$ and local variables $V(\dots)$ as a means of clarifying the effect of certain actions and the conditions under which those actions are valid, local timers $T(\dots)$ as a means of monitoring actions of the distributed DLS-provider and of ensuring a local DLE response to the absence of those actions, and local counters $C(\dots)$ for performing rate measurement functions. It also uses local queues $Q(\dots)$ as a means of ordering certain activities, of clarifying the effects of certain actions, and of clarifying the conditions under which those activities are valid.

Unless otherwise specified, at the moment of their creation or of DLE activation:

- a) all variables shall be initialized to their default value, or to their minimum permitted value if no default is specified;
- b) all counters shall be initialized to zero;
- c) all timers shall be initialized to inactive;
- d) all queues shall be initialized to empty.

DL-management may change the values of configuration variables.

4.6.1.2 Summary of variables, parameters, counters, timers for star-architecture

Table 3 and Table 4 summarize the variables and their usage.

The data types used in the data link variables, parameters, state machines are specified in IEC 61158-5-11, Clause 5. The most significant bit of the most significant octet is always used as the most significant bit of the binary number. The bits of each octet are numbered 0 to 7, where bit 0 is the least significant bit of the octet. Each octet is transferred to the Ph layer low-bit first and multiple octets is transferred low-order octet first (little endian format).

Table 3 – DLE-variables and permissible values of star-architecture

Variable-name	Description	Permissible values	Data type
BW	Length of TCC data word in a DLPDU	The default value is 128 (octets). See 4.6.2.7	UINT
DR	Data-rate	The default value is 100 (Mbps). See 4.6.2.11	UINT
HTh	Maximum observational time period for detecting the continuous high-speed transmission cycle disrupted	2 to $2^{16}-1$ (in units of 1 ms). The default value is $3 \times V(Th)$. See 4.6.2.12	UDINT
HTI	Maximum observational time period for detecting the continuous low-speed transmission cycle disrupted	2 to $2^{16}-1$ (in units of 1 ms). The default value is $3 \times V(Th)$. See 4.6.3.5	UDINT
HTm	Maximum observational time period for detecting the continuous medium-speed transmission cycle disrupted	2 to $2^{16}-1$ (in units of 1 ms). The default value is $3 \times V(Th)$. See 4.6.2.14	UDINT
IA	Individual address of this node	Individual 48-bit address identical to ISO/IEC 8802-3. See 4.6.2.16	USINT[6]
IGP	Time interval from the end of a previous frame to the start of the consecutive frame sent by a node	The default value is 24 (0,96 μ s in units of 0,04 μ s). See 4.6.2.17	UDINT
IP	IP address of this node	32-bit address identical to IPv4. See 4.6.2.18	USINT[4]
MD	Maximum distance on the connection path between any 2 nodes	1 to 100 (km). The default value is 8. See 4.6.2.21	UINT
MDD	Maximum difference of the distance of two redundant physical mediums on the connection path between any 2 nodes	0 to 2 000 (in m). The default value is 500. See 4.6.3.7	UINT
MGA	Multicast group address	Multicast 48-bit address identical to ISO/IEC 8802-3, for logically associated Type 11 fieldbus nodes. The default value is 0x01-0x00-0x5e-0x50-0x00-0x01. See 4.6.2.22	USINT[6]
MN	Maximum node number	254 (default value). See 4.6.2.23	USINT
MPD	Maximum difference of the signal delay time propagating over two redundant physical mediums on the connection path between any 2 nodes	1 to 0x7c (in units of 0,04 μ s). The default value is 0x7c ($\approx 5 \mu$ s). See 4.6.3.8	UDINT
MRT	Maximum number of the repeater units on the connection path between any 2 nodes	0 to 7. The default value is 3. See 4.6.2.24	UINT
MTHT	Maximum-token-hold-time for high-speed cyclic data transmission	1 to $2^{16}-1$ (octet times). The default value is 0x30B4 (= 900 μ s). See 4.6.2.25	UDINT
PBh	List of up to 2 048 data buffers using for sending out high-speed TCC data	1 to 2 048. See 4.6.2.28	UINT
PBI	List of up to 2 048 data buffers using for sending out low-speed TCC data	1 to 2 048. See 4.6.3.10	UINT
PBm	List of up to 2 048 data buffers using for sending out medium-speed time-critical cycle data	1 to 2 048. See 4.6.2.29	UINT
RCS	Receive-channel switching control for receiving frames. Designates the switching control for receiving frames out of one of two receive-channel A and B corresponding to each of the redundant media A and B	“Automatic”, “Force A”, “Force B” “Automatic”: Automatically switch to the proper receive-channel. “Force A”, “Force B”: Force to switch Receive-channel A or B respectively. The default is “Automatic”. See Table 10, Table 12, 4.6.3.12	BOOL

Variable -name	Description	Permissible values	Data type
RMGP	Maximum time-interval for one receive-channel, which has already completed one frame received and has waited for IGP time, to wait for the completion of a frame to be received on the other receive-channel in order to detect the other receive-channel disrupted	250 (in units of 0,04 µs). The value 250 represents 10 µs. See 4.6.3.14	UDINT
ST	The slot-time is the fundamentally observational time unit, used in the DLME for observing to initiate action such as re-initialization in sending out the CLM frame, and also used in the DLME for observing the CMP frame sent by the corresponding node, and in case that the node failed to send out, used in the DLME for initiating action just as the CMP frame is received	1 to 255 (in units of physical symbol times for 512 bits, identical to ISO/IEC 8802-3). The default value is 20 (= 100 µs). See Table 14, 4.6.2.38	USINT
SCMP	Medium-access-control-time for substitute CMP	1 to 255 (in units of physical symbol times for 512 bits, identical to ISO/IEC 8802-3). The default value is 20 (= 100 µs). See 4.6.2.31	USINT
SCMPL	Permissible repetitive count within which the node can behave like that the node received the CMP frame even though the corresponding node had failed to send out the CMP frame. The node determines the corresponding node is out of service if the count is over	1 to 16. The default value is 3. See 4.6.2.33	USINT
SEN _A SEN _B	Send enable control for sending frames out of the transmitter-A or -B	"True" / "Enable" or "False" / "Disable" The default value is "True" / "Enable". See 4.6.3.16	BOOL
Th	High-speed transmission period	1 to 160 (in units of 0,1 ms). See Table 15, 4.6.2.39	USINT[3]
Tl	Low-speed transmission period	1 to 10 000 (in units of 1 ms). See Table 18, 4.6.3.17	UINT
TISPD	Time-interval cyclically processed for Sporadic message data service	1 to 1 000 (in units of 1 ms). The default value is 100. See Table 17, 4.6.2.40, 4.6.2.41	UINT
Tm	Medium-speed transmission period	1 to 1 000 (in units of 1 ms). The default value is 100. See Table 16, 4.6.2.42	UINT
TMAC	Maximum observation time period for the SYN node to solicit new nodes into the Type 11 fieldbus	1 to 100 (in units of 0.1 ms). The default value is 100. See 4.6.2.43, 4.6.2.44	USINT
Tsl	DLE number able to send out next slot	1 to 255. See 4.6.2.46	USINT
TSYN	Target-periodic-time from SYN frame arrival to SYN frame arrival	1 to 160 (in units of 0,1 ms). See 4.6.2.47	UDINT
TTRT0	Target-token-rotation-time for access class 0	1 to 2 ¹⁶ -1 (octet time). The default value is P(TSYN). See 4.6.3.18	UDINT
TTRT1	Target-token-rotation-time for access class 1	1 to 2 ¹⁶ -1 (octet time). The default value is P(TSYN). See 4.6.2.48	UDINT
TTRT2	Target-token-rotation-time for access class 2	1 to 2 ¹⁶ -1 (octet time). The default value is P(TSYN). See 4.6.2.49	UDINT
TN	Node identifier number of the node. The initial value is 0 on power-up or reset	1 to 255. See 4.6.2.45	USINT

Table 4 – Observable variables and their value ranges of star-architecture

Variable -name	Description	Range of value	Data type
AIGP _A AIGP _B	IGP monitor over the receive-channel A and B	0 to 24, continuously decrementing. The value 24 represents 0,96 µs. See 4.6.3.1	UDINT
ARMGP	The observed time period for one receive-channel, which has already completed one frame received and has waited for IGP time (0,96 µs), to wait the completion of a frame received on the other receive-channel in order to detect the other receive-channel disrupted	0 to 250, continuously decrementing. The value 250 represents 10 µs. See 4.6.3.2	UDINT
ASCMP	Collection of counters of total number of nodes. Each counter corresponding to a node indicates observed repetitive count that the corresponding node failed to send out the CMP frame and the other node can behave like that the CMP frame received without error. The node determines the corresponding node is out of service when the count reaches the pre-specified number. The number counted is indicated and is incremented coincidentally at each DLME	1 to 16. The default value is equal to the value of SCMP, which is 3. See 4.6.2.1	USINT
ATHT	The observed time period of the MHT	0 to MHT, continuously decrementing. See 4.6.2.2	UDINT
ATSYN	The observed time period from SYN frame arrival to SYN frame arrival	1 to 2 ¹⁶ (octet times). See 4.6.2.3	UDINT
ATTRT0	The observed time period of the TTRT0	1 to 2 ¹⁶ -1, continuously decrementing. See 4.6.3.3	UDINT
ATTRT1	The observed time period of the TTRT1	1 to 2 ¹⁶ -1, continuously decrementing. See 4.6.2.4	UDINT
ATTRT2	The observed time period of the TTRT2	1 to 2 ¹⁶ -1, continuously decrementing. See 4.6.2.5	UDINT
CDh	Cumulative count of transmitted high-speed-cyclic data frames	0 to 2 ³² -1. See 4.6.2.8	UDINT
CDH _{blk}	Information data status of the data buffer with the identifier number "blk", indicating the corresponding TCC data being active (healthy) or inactive (unhealthy)	True: active. False: inactive. See 4.6.2.9	BOOL
CDI	Cumulative count of transmitted low-speed-cyclic data frames	0 to 2 ³² -1. See 4.6.3.4	UDINT
CDm	Cumulative count of transmitted medium-speed-cyclic data frames	0 to 2 ³² -1. See 4.6.2.10	UDINT
LL	Live list indicating whether the corresponding node, at this moment, is connected to and running in the Type 11 fieldbus domain in the received SYN frame. The Live list is a set of 256 Booleans, represented in 32 octets, in which each bit corresponds to a node in the Type 11 fieldbus domain and indicates the current status of that node	256-bit set of Booleans True: node is connected and working. False: node is not connected or not working. See 4.6.2.19	USINT[16]
LN	Extracted number from LL at each node and used by each node to decide whether the node is able to send the data frame out over the medium	1 to 255. See 4.6.2.20	USINT
NCD _A , NCD _B	Cumulative count of No-Carrier detected on the receive-channel A or B	0 to 2 ³² -1. See 4.6.3.9	UDINT

Variable -name	Description	Range of value	Data type
NONC	Permissible repetitive count of no CMP frame received by the SYN node within the corresponding consecutive Tsyn cycles, that is 256 times by SCMP, in order to detect no other node except the SYN node in the Type 11 fieldbus domain	1 to 16. The default value is 3. See 4.6.2.26, 4.6.2.27	USINT
RE _A , RE _B	Cumulative count of DLPDUs received in error on the receive-channel A or B. RE _A is incremented when an error is detected on receive-channel A while receive-channel B is error-free. RE _B corresponds, but with interchanged channel roles.	0 to 2 ³² -1. See 4.6.3.13	UDINT
ROK _A , ROK _B	Cumulative count of DLPDU-received without error on the receive-channel A or B	0 to 2 ³² -1. See 4.6.3.15	UDINT
SL	The observed time period of the SL	0 to V(SL). See 4.6.2.35, 4.6.2.36	USINT
SD	Cumulative count of transmitted sporadic data frames	0 to 2 ³² -1. See 4.6.2.34	UDINT

4.6.1.3 Summary of variables, parameters, counters, timers for loop-architecture

Table 5 and Table 6 summarise the variables and their usage. The data types used in the data link variables, parameters, state machines are specified in IEC 61158-5-11, Clause 5.

The data types used in the data link variables, parameters, state machines are specified in IEC 61158-5-11, Clause 5. The most significant bit of the most significant octet is always used as the most significant bit of the binary number. The bits of each octet are numbered 0 to 7, where bit 0 is the least significant bit of the octet. Each octet is transferred to the Ph layer low-bit first and multiple octets is transferred low-order octet first (little endian format).

Table 5 – DLE variables and permissible values of loop-architecture

Variable -name	Description	Permissible values	Data type
BW	Length of TCC data word in a DLPDU	16 to 128. The default value is 64. See 4.6.2.7	UINT
DR	Data-rate	The value is 100 or 1 000 (Mbps). See 4.6.2.11	UINT
ESYN	Enable SYN	“Enable” or “Disable”. “Enable” is capable of SYN node. “Disable” is not capable of SYN node. The default value is “Enable”. See 6.4.3, 4.6.4.5	
FWE _{AB} , FWE _{BA}	Forwarding control for receiving frame enable to each direction to/from Ring-port-A and -B. FWE _{AB} controls forwarding frames receiving from Ring-port-A to Ring-port-B. On the other hand, FWE _{BA} controls forwarding frames receiving from Ring-port-B to Ring-port-A	“Enable” or “Disable”. “Enable”: permit forwarding frames receiving from one Ring-port to other Ring-port. “Disable”: prohibit forwarding frames between Ring-ports. The default value is “Disable”. See 6.9.3, 4.6.4.6	BOOL
HTh	Maximum observational time period for detecting the continuous high-speed transmission cycle disrupted	2 to 2 ¹⁶ -1 (in units of: – 1 ms for 100 Mbps operation; – 0,1 ms for 1 000 Mbps operation). The default value is 3 x V(Th). See 4.6.2.12	UDINT
HTI	Maximum observational time period for detecting the continuous low-speed transmission cycle disrupted	2 to 2 ¹⁶ -1 (in units of 1 ms). The default value is 3 x V(Th). See 4.6.4.7	UDINT

Variable -name	Description	Permissible values	Data type
HTm	Maximum observational time period for detecting the continuous medium-speed transmission cycle disrupted	2 to 2 ¹⁶ -1 (in units of 1 ms). The default value is 3 x V(Th). See 4.6.2.14	UDINT
IA	Individual address of this node	Individual 48-bit address identical to ISO/IEC 8802-3. See 4.6.2.16	SWORD[6]
IGP	Time interval from the end of a previous frame to the start of the consecutive frame sent by a node	The default value is: – 24 for 100 Mbps operation; – 12 for 1 000 Mbps operation. See 4.6.2.17	UDINT
IP	IP address of this node	32-bit address identical to IPv4. See 4.6.2.18	USINT[4]
MD	Maximum distance on the connection path between any 2 nodes	1 to 20 (km). The default value is 4. See 4.6.2.21	UINT
MDAD	Maximum distance between adjacent node	The value is: – 1 to 2 (km) for 100 Mbps operation; – .1 to 5 (km) for 1 000 Mbps operation. The default value is 1. See 4.6.4.11	UINT
MGA	Multicast group address	Multicast 48-bit address identical to ISO/IEC 8802-3, for logically associated Type 11 fieldbus nodes. The default value is 0x01-0x00-0x5e-0x50-0x00-0x01. See 4.6.2.22	USINT[6]
MN	Maximum node number	254 (default value). See 4.6.2.23	USINT
MRT	Maximum number of the repeater units on the connection path between any 2 nodes	0 to 252. The default value is 30. See 4.6.2.24	USINT
MTHT	Maximum-token-hold-time for high-speed cyclic data transmission	1 to 2 ¹⁶ -1 (octet time). The default value is 0x30B4 (= 900 µs for 100 Mbps and 90 µs for 1 000 Mbps operation). See 4.6.2.25	UDINT
PBh	List of data buffers using for sending out high-speed TCC data	The value is: – 1 to 2 048 for 100 Mbps operation; – 1 to 4 096 for 1 000 Mbps operation. See 4.6.2.28	UINT
PBI	List of data buffers using for sending out low-speed TCC data	The value is: – 1 to 2 048 for 100 Mbps operation; – 1 to 4 096 for 1 000 Mbps operation. See 4.6.4.16	UINT
PBm	List of data buffers using for sending out medium-speed TCC data	The value is: – 1 to 2 048 for 100 Mbps operation; – 1 to 4 096 for 1 000 Mbps operation. See 4.6.2.29	UINT
PS _A PS _B	Port state control for blocking or non-blocking frame receiving from the Ring-port-A or -B	“Blocked” or “Non-blocked”. The default value is “Blocked”. See Table 27, 4.6.4.18	BOOL
REN _A REN _B	Receive enable control for receiving frames from the Ring-port-A or -B.	“Enable” or “Disable”. The default value is “Enable”. See Table 28, 4.6.4.20	BOOL
ST	The slot-time is the fundamentally observational time unit, used in the DLME for observing to initiate action such as re-initialization in sending out the CLM frame, and also used in the DLME for observing the CMP frame sent by the corresponding node, and in case that the node failed to send out, used in the DLME for initiating action just as the CMP frame is received	1 to 255 (in units of physical symbol times for 512 bits in 100 Mbps operation and for 4 096 bits in 1 000 Mbps operation, identical to ISO/IEC 8802-3). The default value is 20 (= 100 µs for 100 Mbps, and 8 µs for 1 000 Mbps operation). See Table 14, 4.6.2.38	USINT

Variable -name	Description	Permissible values	Data type
SCMP	Medium-access-control-time for substitute CMP	1 to 255 (in units of physical symbol times for 512 bits in 100 Mbps operation and for 4 096 bits in 1 000 Mbps operation, identical to ISO/IEC 8802-3). The default value is 20 (=100 µs for 100 Mbps, and 8 µs for 1 000 Mbps operation). See 4.6.2.31	USINT
SCMPL	Permissible repetitive count within which the node can behave like that the node received the CMP frame even though the corresponding node had failed to send out the CMP frame. The node determines the corresponding node is out of service if the count is over	1 to 16. The default value is 3. See 4.6.2.33	USINT
SEN _A SEN _B	Send enable control for sending frames out of the Ring-port-A or -B	"True" / "Enable" or "False" / "Disable". The default value is "True" / "Enable". See Table 25, 4.6.4.22	BOOL
Th	High-speed transmission period	1 to 160 (in units of 0,1 ms). See Table 15, 4.6.2.39	USINT[3]
Tl	Low-speed transmission period	1 to 10 000 (in units of 1 ms). The default value is 100. See Table 18, 4.6.4.23	UINT
TISPD	Time-interval cyclically processed for Sporadic message data service	1 to 1 000 (in units of 1 ms). The default value is 100. See Table 17, 4.6.2.40, 4.6.2.41	UINT
Tm	Medium-speed transmission period	10 to 1 000 (in units of 1 ms). The default value is 100. See Table 16, 4.6.2.42	UINT
TMAC	Maximum observation time period for the SYN node to solicit new nodes into the Type 11 fieldbus	1 to 100 (in units of 0.1 ms for 100 Mbps and of 0,01 ms for 1 000 Mbps operation). The default value is 100. See 4.6.2.43, 4.6.2.44	USINT
Tsl	DLE number able to send out next slot	1 to 255. See 4.6.2.46	USINT
TSYN	Target-periodic-time from SYN frame arrival to SYN frame arrival	1 to 160 (in units of 0,1 ms). See 4.6.2.47	UDINT
TTRT0	Target-token-rotation-time for access class 0	1 to 2 ¹⁶ -1 (octet time). The default value is P(TSYN). See 4.6.4.24	UDINT
TTRT1	Target-token-rotation-time for access class 1	1 to 2 ¹⁶ -1 (octet time). The default value is P(TSYN). See 4.6.2.48	UDINT
TTRT2	Target-token-rotation-time for access class 2	1 to 2 ¹⁶ -1 (octet time). The default value is P(TSYN). See 4.6.2.49	UDINT
TN	Node identifier number of the node. The initial value is 0 on power-up or reset	1 to 255. See 4.6.2.45	USINT

Table 6 – Observable variables and their value ranges of loop-architecture

Variable -name	Description	Range of value	Data type
AN _A AN _B	Node number of adjacent node neighboring Ring-port-A or -B	1 to 254. See 4.6.4.1	USINT
ASCMP	Collection of counters of total number of nodes. Each counter corresponding to a node indicates observed repetitive count that the corresponding node failed to send out the CMP frame and the other node can behave like that the CMP frame received without error. The node determines the corresponding node is out of service when the count reaches the pre-specified number. The number counted is indicated and is incremented coincidentally at each DLME	1 to 16. The default value is equal to the value of SCMPL, which is 3. See 4.6.2.1	USINT
ATHT	The observed time period of the MHTT	0 to MHTT, continuously decrementing. See 4.6.2.2	UDINT
ATSYN	The observed time period from SYN frame arrival to SYN frame arrival	1 to 2 ¹⁶ (octet times). See 4.6.2.3	UDINT
ATTRT0	The observed time period of the TTRT0	1 to 2 ¹⁶ -1, continuously decrementing. See 4.6.4.2	UDINT
ATTRT1	The observed time period of the TTRT1	1 to 2 ¹⁶ -1, continuously decrementing. See 4.6.2.4	UDINT
ATTRT2	The observed time period of the TTRT2	1 to 2 ¹⁶ -1, continuously decrementing. See 4.6.2.5	UDINT
CDh	Cumulative count of transmitted high-speed-cyclic data frames	0 to 2 ³² -1. See 4.6.2.8	UDINT
CDH _{blk}	Information data status of the data buffer with the identifier number "blk", indicating the corresponding TCC data being active (healthy) or inactive (unhealthy)	True: active. False: inactive. See 4.6.2.9	BOOL
CDm	Cumulative count of transmitted medium-speed-cyclic data frames	0 to 2 ³² -1. See 4.6.2.10	UDINT
CRE _A CRE _B	Observed repetitive count for the abnormal reception error detected during receiving incoming frame from the Ring-port-A or -B respectively. The count is decreased by each abnormal reception detection repetitively but reset to the initial value when the abnormal reception is cleared. When reached to 0, abnormal reception error is detected	0 to 15. The default value is 2. See 4.6.4.4	USINT
LINK _A LINK _B	Link state indicating the condition of physical link connection at Ring-port-A or -B	"Abnormal" or "Normal". See 4.6.4.9	BOOL
LSYN	Node number of the node in current master state	1 to 254. See 4.6.4.10	USINT
LL	Live list indicating whether the corresponding node, at this moment, is connected to and running in the Type 11 fieldbus domain in the received SYN frame. The Live list is a set of 256 Booleans, represented in 32 octets, in which each bit corresponds to a node in the Type 11 fieldbus domain and indicates the current status of that node	256-bit set of Booleans. True: node is connected and working. False: node is not connected or not working. See 4.6.2.19	USINT[16]
LN	Extracted number from LL at each node and used by each node to decide whether the node is able to send the data frame out over the medium	1 to 255. See 4.6.2.20	USINT
NCD _A , NCD _B	Cumulative count of No-Carrier detected on the Ring-port-A or B	0 to 2 ³² -1. See 4.6.4.12	UDINT

Variable -name	Description	Range of value	Data type
NONC	Permissible repetitive count of no CMP frame received by the SYN node within the corresponding consecutive Tsyn cycles, that is 256 times by SCMPL, in order to detect no other node except the SYN node in the Type 11 fieldbus domain	1 to 16. The default value is 3. See 4.6.2.26, 4.6.2.27	USINT
NOS	Node operation state indicating the operation condition of a node in normal or open state	"Normal" or "Open". The default value is "Open". See 4.6.4.13	BOOL
NRF _A , NRF _B	Observed time period in which no frame received from Ring-port-A or -B after from other Ring-port-B or -A respectively, a frame has been received	0 to 15 (in units of Th time). The default value is 2. See 4.6.4.14	USINT
NS	Node state indicating the node condition operating as master or slave	"Master" or "Slave". The default value is "Slave". See 4.6.4.15	BOOL
PP	Primary port indicating the Ring-port-A or -B through which SYN or CLM received first since this node is power-up, or in the system start-up, or in the system initialization	"Ring-port-A" or "Ring-port-B". The default value is "Ring-port-A". See Table 26, 4.6.4.17	BOOL
RE _A , RE _B	Cumulative count of DLPDUs received in error on the Ring-port-A or -B. RE _A is incremented when an error is detected on the Ring-port-A while the Ring-port-B respectively is error-free. RE _B corresponds, but with interchanged channel roles	0 to 2 ³² -1. See 4.6.4.20	UDINT
ROK _A , ROK _B	Cumulative count of DLPDU-received without error on the Ring-port-A or -B	0 to 2 ³² -1. See 4.6.4.21	UDINT
SL	The observed time period of the SL	0 to V(SL). See 4.6.2.35, 4.6.2.36	USINT
SD	Cumulative count of transmitted sporadic data frames	0 to 2 ³² -1. See 4.6.2.34	UDINT

4.6.2 Type 11 common variables, parameters, counters, timers and queues

4.6.2.1 C(ASCMP) : ASCMP count

A collection of counters, each of which indicates the number of observed repetitive count that the corresponding node failed to send out the CMP frame and the other node can behave like that the CMP frame received without error. The number of C(ASCMP) is incremented coincidentally at each node in Type 11 fieldbus. The value is in the range of 1 to V(SCMPL) and the default value is 3.

4.6.2.2 T(ATHT) : MTHT monitor

T(ATHT) is used by the DLE to measure the time elapsed of MTHT. The value is decremented in the range of P(MTHT) to 0.

4.6.2.3 T(ATSYN) : TSYN monitor

T(ATSYN) is used by the DLE to monitor the time period from SYN frame arrival to SYN frame arrival. The value is indicated in octet time by the data signaling rate.

4.6.2.4 T(ATTRT1) : TTRT1 monitor

T(ATTRT1) is used by the DLE to monitor the time period of TTRT1. The value is decremented in the range of 2¹⁶-1 to 1, of which unit is in octet time by the data-signaling rate.

4.6.2.5 T(ATTRT2) : TTRT2 monitor

T(ATTRT2) is used by the DLE to monitor the time period of TTRT2. The value is decremented in the range of $2^{16}-1$ to 1, of which unit is in octet time by the data-signaling rate.

4.6.2.6 Q(BF_{blk}) : Data buffer used for sending and receiving a DLPDU for time-critical cyclic data DLPDU

The total number of buffers is equivalent of the total number of DLCEP. Each buffer with the identifier “_{blk}” number corresponds to a DLCEP with the identifier number “identifier”.

4.6.2.7 V(BW), P(BW) : Length of time-critical cyclic data word in a DLPDU

This variable holds and designates the length of the Time-critical cyclic data word in a DLPDU.

The possible value of the length in octet is as follows:

- a) star-architecture: The default value is 128;
- b) loop-architecture: 16 to 128. The default value is 64.

4.6.2.8 C(CDh) : Cumulative count of high-speed-cyclic data frame sent

C(CDh) indicates the number of cumulative count of high-speed-cyclic data frame sent on the medium. C(CDh) is a roll-over binary counter of 32-bit length.

4.6.2.9 V(CDH_{blk}) Information data status of the data buffer with identifier number “_{blk}”

This variable indicates the status of the corresponding time-critical cyclic data being active (healthy) or inactive (unhealthy). The value “True” indicates active, and the value “False” indicates inactive.

4.6.2.10 C(CDm) : Cumulative count of medium-speed-cyclic data frame sent

C(CDm) indicates the number of cumulative count of medium-speed-cyclic data frame sent on the medium. C(CDm) is a roll-over binary counter of 32 bits length.

4.6.2.11 V(DR) : Data-rate

The value of this variable indicates the data signaling rate in Mbps. The value is 100 for the star-architecture and is either 100 or 1 000 for the loop-architecture.

4.6.2.12 V(HTh), P(HTh) : Maximum observational time period for detecting the continuous high-speed transmission cycle disrupted

This variable holds and designates the value of maximum observational time period for detecting the continuous High-speed transmission cycle disrupted. The value of this variable is in the range of 2 to $2^{16}-1$, of which the unit is 1 ms in 100 Mbps and 0,1 ms in 1 000 Mbps operation. The default value is $3 \times V(Th)$.

4.6.2.13 T(HTh) : HTh monitor

T(HTh) is used by the DLE to measure the HTh time elapsed to detect the continuous High-speed transmission cycle failed. The value is decremented in the range of V(HTh) to 1.

4.6.2.14 V(HTm), P(HTm) : Maximum observational time period for detecting the continuous medium-speed transmission cycle disrupted

This variable holds and designates the value of maximum observational time period for detecting the continuous Medium-speed transmission cycle disrupted. The value of this variable is in the range of 2 to $2^{16}-1$, of which the unit is 1ms. The default value is $3 \times V(Th)$.

4.6.2.15 T(HTm) : HTm monitor

T(HTm) is used by the DLE to measure the HTm time elapsed to detect the continuous Medium-speed transmission cycle disrupted. The value is decremented in the range of V(HTm) to 1.

4.6.2.16 V(IA) : Individual-address-of-this-node

This variable holds the individual address of this node in the 48-bit length specified by ISO/IEC 8802-3. The value is set by DLMS.

4.6.2.17 V(IGP) : Inter-frame-time-gap

This variable indicates the value of the time interval from the end of a previous frame to the start of the consecutive frame sent by a node. The value is equivalent to 0,96 μ s for 100 Mbps and 0,096 μ s for 1 000 Mbps operation and is identical to that specified by ISO/IEC 8802-3.

4.6.2.18 V(IP), P(IP) : IP address of this node

This variable holds and designates DLSAP value assigned for Type 11 fieldbus Sporadic message data service.

4.6.2.19 V(LL) : Live-list

This variable indicates the current operational status, whether a corresponding node is connecting to and is running normally in the Type 11 fieldbus. The possible value is "True" or "False", "True" means the node is connecting to and working normally and "False" is not. V(LL) is used by the DLE and is generated from the information conveyed by SYN frame. Live-list is a collection of 8 words of 32-bit length, each bit of which corresponds to the node in the Type 11 fieldbus and indicates the current operational status. Each bit corresponds to the node number V(TN) in a sequential order from 0 to 255 in little endian format.

4.6.2.20 V(LN) : Live-node-number

This variable indicates the TN number of node, extracted from V(LL), which connects to and is running normally in the Type 11 fieldbus at this point. V(LN) is used by the DLE to decide whether the node is able to send the data frame out over the medium. The range of this value is 1 to 255.

4.6.2.21 V(MD), P(MD) : Maximum-distance

The value of this variable holds, and is set by DLMS, the maximum distance in kilometer on the connection path between any 2 nodes.

The range of this value is as follows:

- a) star-architecture: 1 to 100, and the default value is 8;
- b) loop-architecture: 1 to 20, and the default value is 4.

4.6.2.22 V(MGA), P(MGA) : Multicast group address

This variable holds and designates the multicast group address, used by the DLE to build logically associated group of the Type 11 fieldbus nodes, in 48-bit length specified by and identical to ISO/IEC 8802-3. The default value is 0x01-0x00-0x5e-0x50-0x00-0x01.

4.6.2.23 V(MN), P(MN) : Maximum-node-number

This variable holds the maximum node number, and is set by DLMS. The default value of this variable is 254.

4.6.2.24 V(MRT), P(MRT) : Maximum-number-of-the-repeater-unit

This variable holds, and is set by the DLMS, maximum number of the repeater units on the connection path between any 2 nodes.

The possible value is as follows:

- a) star-architecture: 0 to 7, and the default value is 3;
- b) loop-architecture: 0 to 252, and the default value is 30.

4.6.2.25 V(MTHT), P(MTHT) : Maximum-token-hold-time

This variable holds and designates the value of maximum-token-hold-time for high-speed cyclic data transmission. The range of this value is 1 to $2^{16}-1$ of which unit is in octet time by the data signaling rate. The default value is 0x30B4, that is approx. 900 μ s for 100 Mbps and 90 μ s for 1 000 Mbps operation.

4.6.2.26 V(NONC), P(NONC) : Permissible repetitive count of no CMP

This variable holds and designates the value of permissible repetitive count of no CMP frame received by the SYN node within the corresponding consecutive Tsyn cycles, that is 256 times by V(SCMPL), in order to detect no other node except the SYN node in the Type 11 fieldbus. The range of this value is 1 to 16, and the default value is 3.

4.6.2.27 C(NONC) : NONC count

C(NONC) indicates the number of repetitive count of no CMP frame received by the SYN node within $V(MN) \times V(SCMPL)$ of the consecutive Tsyn cycles. C(NONC) reached to the number of V(NONC), the SYN node detects and recognizes no other node hooking up to the Type 11 fieldbus.

4.6.2.28 V(PBh), P(PBh) Maximum number of the data buffers used for sending high-speed time-critical cyclic data

This variable holds and designates the maximum number of the data buffers used for sending high-speed time-critical cyclic data.

4.6.2.29 V(PBm), P(PBm) Maximum number of the data buffers used for sending medium-speed time-critical cyclic data

This variable holds and designates the maximum number of the data buffers used for sending medium-speed time-critical cyclic data.

4.6.2.30 Q(QBF_{SPD}) : Queue buffer for sporadic data

The queue buffer for the Sporadic message data service holds the DLPDU by DL-user to be sent. The queue buffer size to transfer as well as to receive the Sporadic message data is implementation matter.

4.6.2.31 V(SCMP), P(SCMP) : Medium-access-control-time for substitute CMP

This variable holds and designates the value of maximum observational time period for the node to initiate the action like that the node received the CPM frame even though the corresponding node failed to send out the CMP frame.

4.6.2.32 T(SCMP) : SCMP monitor

T(SCMP) is used by the DLE of the node to measure the SCMP time elapsed to initiate the action like that the node received the CMP frame even though the corresponding node failed to send out the CMP frame. The value is decremented in the range of V(SCMP) to 0.

4.6.2.33 V(SCMPL), P(SCMPL) : Permissible repetitive count of substitute CMP

This variable holds and designates the value of permissible repetitive count within which the node can behave like that the node received the CMP frame without error even though the corresponding node failed to send out the CMP frame. The range of this value is 1 to 16 and the default value is 3.

4.6.2.34 C(SD) : Cumulative count of sporadic data frame sent

C(SD) indicates the number of cumulative count of sporadic data frames sent on the medium. C(SD) is a roll-over binary counter of 32-bit length.

4.6.2.35 V(SL), P(SL) : Silence time

This variable holds and designates the value of the silence time or inactivity time period for detecting the current SYN node out of order, following to initiate sending the CLM frame out from this node in order to claim new SYN node if this node is designated and permitted to be a SYN node. The value is set by the DLE to the T(SL) timer as follows:

$$T(SL) = V(TSYN) + V(ST) \times V(TN) \times 2$$

4.6.2.36 T(SL) : SL monitor

T(SL) is used by the DLE to measure the time elapsed of SL. The value is decremented in the range of V(SL) to 0.

4.6.2.37 V(SM), P(SM) : Subnet address mask

This variable holds and designates the value of subnet address mask for V(IP) for Type 11 fieldbus Sporadic message data service.

4.6.2.38 V(ST), P(ST), T(ST) : Type 11 fieldbus slot-time

Slot-time is the fundamentally observational time unit, used in the DLME for observation of initiation of the action such as re-initialization in sending out the CLM frame, for observation of initiation of the action that the node behaves like the CMP frame received even though the corresponding node failed to send out the CMP frame.

This variable holds and designates the fundamentally observational time value of slot time. The range of the value is 1 to 255, of which time is in 512-bit physical symbol time for 100 Mbps operation and in 4 096 bit physical symbol time for 1 000 Mbps operation specified by and identical to ISO/IEC 8802-3. The default value is 20, which is equivalent to Approx.100 μs for 100 Mbps operation and 8 μs for 1 000 Mbps operation, i.e. $20 \times 512 \times 1/100 \mu s$ in case of 100 Mbps operation.

The slot time value is calculated from the following formula:

$$V(ST) = \text{round up } [2 \times V(MD) + V(MRT)/2 + 2]$$

4.6.2.39 V(Th), P(Th) : High-speed transmission period

This variable holds and designates the cyclic time period of High-speed time-critical data transmission. P(Th) is used by the DLE and the value is set to V(SYN). The range of this value is 1 to 160, of which the unit is 0,1ms. The default value is 100.

4.6.2.40 V(TISPD), P(TISPD) : Time-interval for sporadic-message-data-service

This variable holds and designates the value of time interval cyclically processed for Sporadic-message-data service. The range of this value is 1 to 1 000, of which unit is in 1 ms. The default value is 100.

4.6.2.41 T(TISPD) : TISPD monitor

T(TISPD) is used by the DLE to measure the time interval of TISPD.

4.6.2.42 V(Tm), P(Tm) : Medium-speed transmission period

This variable holds and designates the cyclic time period of Medium-speed time-critical data transmission. P(Tm) is used by the DLE. The range of this value is 1 to 1 000, of which the unit is 1ms. The default value is 100.

4.6.2.43 V(TMAC), P(TMAC) : Medium-access-control-time to solicit new nodes

This variable holds and designates the value of maximum observational time period for the SYN node to solicit new nodes into the Type 11 fieldbus. During the time period new nodes attempt to send out the REQ frame to the SYN node. The default value is 100, the unit of which is in 0,1 ms for 100 Mbps operation and in 0,01 ms for 1 000 Mbps operation.

4.6.2.44 T(TMAC) : TMAC monitor

T(TMAC) is used by the DLE of the SYN node to measure the time elapsed of TMAC in order to wait for REQ frames sent from node which attempts to enter the Type 11 fieldbus. The value is decremented in the range of V(TMAC) to 0.

4.6.2.45 V(TN), P(TN) : This-node

This variable holds and designates the node identifier number of this node. The initial value is 0 on power-up or reset of this node. The range of this value is 1 to 255.

4.6.2.46 V(Tsl) : DLE number able to send out next slot

This variable is used by the DLE to hold and indicate the node identifier number of V(TN) of which the node can send out its data next in the sequential order in succession to a node currently having completed sending out all its data and CMP or DT-CMP DLPDU. The value of this variable is updated and set to the value of V(TN) of the node next to send out, every time on the reception of CMP or DT-CMP DLPDU. The range of this variable is 1 to 255.

4.6.2.47 V(TSYN) : Target-periodic-time of synchronization

This variable indicates the target time period from SYN frame arrival to SYN frame arrival. The value is equal to V(Th), and the value of P(Th) is used by the DLMS and is set to V(Th). The possible range of this time period is 0,1 ms to 160 ms. V(SYN) and V(Th) indicate the cyclic time period in which all the node with high-speed cyclic data can obtain the transmission right to send out all of the high-speed cyclic data.

4.6.2.48 V(TTTR1), P(TTTR1) : Target-token-rotation-time for access class 1

This variable holds and designates the value of target-token-rotation-time for access class 1, especially for sporadic message data transmission. The range of this value is 1 to $2^{16}-1$ of which unit is in octet time by the data signaling rate. The default value is equal to P(TSYN). This value is used by the DLE and should be equal and common to all DLEs of the Type 11 fieldbus.

P(TTTR1) is used by the DLME and the value is the time period in which a node with sporadic message data can expect to obtain the transmission right to send out.

4.6.2.49 V(TTTR2), P(TTTR2) : Target-token-rotation-time for access class 2

This variable holds and designates the value of target-token-rotation-time for access class 2, especially for medium-speed cyclic data transmission. The range of this value is 1 to $2^{16}-1$ of which

unit is in octet time by the data signaling rate. The default value is equal to $P(TSYN)$. This value is used by the DLE and should be equal and common to all DLEs of the Type 11 fieldbus.

$P(TTR2)$ is used by the DLME, and the value is the expected time period in which all nodes with medium-speed cyclic data can obtain the transmission right and send out all of the medium-speed cyclic data.

4.6.3 Star-architecture specific variables, parameters, counters, timers and queues

4.6.3.1 $T(AIGP_A)$, $T(AIGP_B)$: IGP monitor over the receive-channel A and B

$T(AIGP_A)$ and $T(AIGP_B)$ are used by the DLE to measure the time elapsed of IGP over the receive-channel A and B respectively. The value is decremented in the range of 24 to 0, and value 24 is equivalent to 0,96 μs .

4.6.3.2 $T(ARMGP)$: RMGP monitor

$T(ARMGP)$ is used by the DLE to monitor the time elapsed of RMGP. The value is decremented in the range of 250 to 0, and value 250 is equivalent to 10 μs .

4.6.3.3 $T(ATTRT0)$: TTRT0 monitor

$T(ATTRT0)$ is used by the DLE to monitor the time period of TTRT0. The value is decremented in the range of $2^{16}-1$ to 1, of which unit is in octet time by the data-signaling rate.

4.6.3.4 $C(CDI)$: Cumulative count of low-speed-cyclic data frame sent

$C(CDI)$ indicates the number of cumulative count of low-speed-cyclic data frames sent on the medium. $C(CDI)$ is a roll-over binary counter of 32-bit length.

4.6.3.5 $V(HTI)$, $P(HTI)$: Maximum observational time period for detecting the continuous low-speed transmission cycle

This variable holds and designates the value of maximum observational time period for detecting the continuous Low-speed transmission cycle disrupted. The value is in the range of 2 to $2^{16}-1$, of which the unit is 1ms. The default value is $3 \times V(Th)$.

4.6.3.6 $T(HTI)$: HTI monitor

$T(HTI)$ is used by the DLE to measure the HTI time elapsed to detect the continuous Low-speed transmission cycle disrupted. The value is decremented in the range of $V(HTI)$ to 1.

4.6.3.7 $V(MDD)$, $P(MDD)$: Maximum-difference-of-the-distance

This variable holds, and is set by DLMS, the maximum difference in meter of the distance of two redundant physical mediums on the connection path between any 2 nodes. The range of this value is 0 to 2 000, and the default value is 500.

4.6.3.8 $V(MPD)$, $P(MPD)$: Maximum-distance-of-the-signal-propagate-delay

This variable holds, and is set by DLMS, the maximum difference in microsecond of the signal delay time propagating over two redundant physical mediums on the connection path between any 2 nodes. The range of this value is 1 to 0x7c, and the default value is 0x7c which is equivalent to approx. 5 μs , i.e. $0x7c (=124) \times 0,04 \mu s$.

4.6.3.9 C(NCD_A), C(NCD_B) : Cumulative count of non-carrier detected on the receive-channel A or B

C(NCD_A) or C(NCD_B) indicates the number of cumulative count of non-carrier detected on one receive-channel while the carrier occurs on the other side of receive-channel. C(NCD_A) and C(NCD_B) are roll-over binary counters of 32-bit length.

4.6.3.10 V(PBI), P(PBI) : Maximum number of the data buffers used for sending low-speed time-critical cyclic data

This variable holds and designates the maximum number of the data buffers used for sending low-speed time-critical cyclic data. The value is 0 to 2 048.

4.6.3.11 V(RCS), P(RCS) : Receive-channel switching control for receiving frames

This variable holds and designates the switching control for receiving frames out of one of two receive-channel A and B corresponding to each of the redundant medium A and B.

The possible value is "Automatic", "Force A" or "Force B". "Automatic" indicates that the switching control for receiving frames is automatically to switch to the proper receive-channel. "Force A" or "Force B" indicates that the switching control is forced to switch to Receive-channel A or B respectively. The default value is "Automatic".

4.6.3.12 V(RCS_A), V(RCS_B) : Receive-channel A or B selected for receiving frames

This variable indicates the corresponding receive-channel is selected for receiving frames from the other node. The value "True" indicates that the corresponding receive-channel is selected, and "False" is not.

4.6.3.13 C(RE_A), C(RE_B) : Cumulative count of DLPDU received with error on the receive-channel A or B

C(RE_A) or C(RE_B) indicates the number of cumulative count of DLPDU received with error while on the other side of the receive-channel no error occurs. C(RE_A) and C(RE_B) are roll-over binary counters of 32-bit length.

4.6.3.14 V(RMGP), P(RMGP) : IGP over other redundant media

This variable holds and designates the value of maximum time-interval for one receive-channel, which has already completed one frame received and has waited for IGP time, to wait the completion of a frame to be received on the other receive-channel in order to detect the other receive-channel disrupted. The default value is 250, of which unit is in 0,04 μs, and is equivalent to 10 μs.

4.6.3.15 C(ROK_A), C(ROK_B) : Cumulative count of DLPDU received without error on the receive-channel A or B

C(ROK_A) or C(ROK_B) indicates the number of the cumulative count of DLPDU received without error on the receive-channel A or B respectively. C(ROK_A) and C(ROK_B) are roll-over binary counters of 32-bit length.

4.6.3.16 V(SEN_A), P(SEN_A); V(SEN_B), P(SEN_B) : Transmitter A or B enabled to send out frames

This variable designates the transmitter A or B enable to send out frames from, and indicates the state of the transmitter A or B being enabled or disabled. The value "True" is to be enabled and "False" is not for the corresponding Transmitter A or B. The default value is "True".