DEUTSCHE NORM

August 2020

DIN EN IEC 61158-4-12

ICS 35.100.20; 35.160

Ersatz für
DIN EN 61158-4-12:2015-09
Siehe Anwendungsbeginn

Industrielle Kommunikationsnetze – Feldbusse – Teil 4-12: Protokollspezifikation des Data-Link Layer (Sicherungsschicht) – Typ 12-Elemente (IEC 61158-4-12:2019); Englische Fassung EN IEC 61158-4-12:2019, nur auf CD-ROM

Industrial communication networks –
Fieldbus specifications –
Part 4-12: Data-link layer protocol specification – Type 12 elements
(IEC 61158-4-12:2019);
English version EN IEC 61158-4-12:2019, only on CD-ROM

Réseaux de communication industriels –
Spécifications des bus de terrain –
Partie 4-12: Spécification du protocole de la couche liaison de données – Éléments de type 12
(IEC 61158-4-12:2019);
Version anglaise EN IEC 61158-4-12:2019, seulement en CD-ROM

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DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN und VDE

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Full document details: DIN EN IEC 61158-4-12:2020-08

Anwendungsbeginn

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

Für DIN EN 61158-4-12:2015-09 besteht eine Übergangsfrist bis 2022-05-23.

Nationales Vorwort

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

Dieser Entwurf betrifft auch die Normen DIN EN IEC 61158-4-2:2020-08, DIN EN IEC 61158-4-3:2020-08, DIN EN IEC 61158-4-4:2020-08, DIN EN IEC 61158-4-19:2020-08, DIN EN IEC 61158-4-21:2020-08, DIN EN IEC 61158-4-24:2020-08 und DIN EN IEC 61158-4-25:2020-08.

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

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

Da sich die Benutzer der vorliegenden Norm der englischen Sprache als Fachsprache bedienen, wird die Englische Fassung der EN IEC 61158-4-12 veröffentlicht. Zu deren Abschnitt 1, der den Anwendungsbereich festlegt und Abschnitt 3 (außer Unterabschnitte 3.1, 3.2, 3.5, 3.6 und 3.7), der die Begriffe festlegt, wurde eine Übersetzung angefertigt und als informativer Nationaler Anhang NA der vorliegenden Norm hinzugefügt. Für die meisten der verwendeten Begriffe existieren keine gebräuchlichen deutschen Benennungen, da sich die deutschen Anwender in der Regel ebenfalls der englischen Benennungen bedienen. Diese Norm steht nicht in unmittelbarem Zusammenhang mit Rechtsvorschriften und ist nicht als Sicherheitsnorm anzusehen.

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

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

Änderungen

Gegenüber DIN EN 61158-4-12:2015-09 wurden folgende Änderungen vorgenommen:

a) technische Korrekturen und redaktionelle Verbesserungen zur Klarstellung;

b) sonstige redaktionelle Verbesserungen.

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 61158-4-12: 2008-09, 2013-01, 2015-09

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Nationaler Anhang NA
(informativ)

Auszugsweise Übersetzung

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

EINLEITUNG

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

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

a) als Leitfaden für Implementierer und Konstrukteure;

b) zur Verwendung bei der Prüfung und Beschaffung von Ausrüstung;

c) als Teil einer Vereinbarung über die Zulassung von Systemen in der offenen Systemumgebung;

d) als eine Erweiterung des Verständnisses von zeitkritischer Kommunikation innerhalb der OSI.

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

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

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

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1 Anwendungsbereich

1.1 Allgemeines

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

Dieses Protokoll stellt Kommunikationsmöglichkeiten für alle teilnehmenden Data-Link-Instanzen bereit:

a) synchron startend zyklisch und

b) zyklisch oder azyklisch asynchron, wie jeden Zyklus durch jede dieser Data-Link-Instanzen angefordert.

Somit kann dieses Protokoll als eines charakterisiert werden, das zyklischen oder azyklischen Zugang asynchron bereitstellt, aber mit einem synchronen Neustart jedes Zyklus.

1.2 Spezifikationen

Dieses Dokument legt fest:

a) Verfahren für den Transfer von Daten und Steuerinformationen von einer Data-Link-Benutzerinstanz zu einer oder mehreren Benutzerinstanzen;

b) die Struktur der DLPDU, die für den Transfer von Daten und Steuerinformationen durch das Protokoll dieses Dokuments verwendet werden, und deren Darstellung als physische Schnittstellendateneinheiten.

1.3 Verfahren

Die Verfahren sind definiert hinsichtlich:

a) der Interaktionen zwischen DL-Instanzen (DLE, DL-entities) über den Austausch von DLPDU;

b) der Interaktionen zwischen einem DL-Dienst-(DLS, DL-service)-Anbieter und einem DLS-Benutzer in demselben System über den Austausch von DLS-Primitiven;

c) der Interaktionen zwischen einem DLS-Anbieter und den MAC-Diensten nach ISO/IEC/IEEE 8802-3.

1.4 Anwendbarkeit

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

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

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1.5 Konformität

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

3 Begriffe, Symbole, Abkürzungen und Vereinbarungen

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

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

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

3.3 Allgemeine Begriffe

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe.

3.3.1
Rahmen
(en: frame)
umgangssprachliches Synonym für DLPDU

3.3.2
DL-Gruppenadresse
(en: group DL-address)
DL-Adresse, die möglicherweise mehr als einen DLSAP innerhalb des erweiterten Verbindungszweigs kennzeichnet

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

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

3.3.3
Knoten
(en: node)
einzelne DL-Instanz, wie sie auf einem lokalen Verbindungszweig existiert

3.3.4
empfangender DLS-Benutzer
(en: receiving DLS-user)
Benutzer der DL-Dienste, der als Empfänger von DLS-Benutzerdaten agiert

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

3.3.5
sendender DLS-Benutzer
(en: sending DLS-user)
Benutzer der DL-Dienste, der als Quelle von DLS-Benutzerdaten agiert

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3.4 Zusätzliche Typ-12-Definitionen

3.4.1
Anwendung
(en: application)
Funktion oder Datenstruktur, für die Daten konsumiert oder produziert werden

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

3.4.2
Anwendungsobjekte
(en: application objects)
mehrere Objektklassen, die zur Laufzeit für einen Nachrichtenaustausch im Netzwerk und innerhalb des Netzwerkgerätes sorgen und diesen verwalten

3.4.3
Basis-Slave
(en: basic slave)
Slave-Gerät, das nur die physische Adressierung von Daten unterstützt

3.4.4
Bit
(en: bit)
Informationseinheit, die aus einer 1 oder einer 0 besteht

Anmerkung 1 zum Begriff: Dies ist die kleinste Dateneinheit, welche übertragen werden kann.

3.4.5
Client
(en: client)
<object> Objekt, das die Dienste eines anderen (Server-)Objekts zur Ausführung einer Aufgabe nutzt

3.4.6
Client
(en: client)
<message> Initiator einer Nachricht, auf die ein Server reagiert

3.4.7
Verbindung
(en: connection)
logische Verknüpfung zwischen zwei Anwendungsobjekten in demselben Gerät oder in unterschiedlichen Geräten

3.4.8
Zyklisch
(en: cyclic)
Ereignisse, die sich regelmäßig wiederholen

3.4.9
zyklische Redundanzprüfung
(en: cyclic redundancy check)
CRC
Restwert, der aus einem Feld von Daten errechnet und als repräsentative Signatur für das Feld verwendet wird

3.4.10
Daten
(en: data)
allgemeine Bezeichnung für jegliche über einen Feldbus übertragene Informationen

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3.4.11
Datenkonsistenz
(en: data consistency)
Mittel für die kohärente Übertragung des Eingabe- oder Ausgabedatenobjekts zwischen Client und Server und für den kohärenten Zugriff auf das Eingabe- oder Ausgabedatenobjekt innerhalb von Client und Server

3.4.12
Gerät
(en: device)
an den Feldbus angeschlossene physische Instanz, die aus mindestens einem Kommunikationselement (dem Netzelement) besteht und die ein Steuerungselement und/oder ein Abschlusselement (Wandler, Aktuator usw.) enthalten darf

[QUELLE: IEC 61158-2, 3.1.13]

3.4.13
verteilte Uhren
(en: distributed clocks)
Methode zur Synchronisierung von Slaves und zur Aufrechterhaltung einer globalen Zeitbasis

3.4.14
Fehler
(en: error)
Nichtübereinstimmung zwischen einem berechneten, beobachteten oder gemessenen Wert oder Zustand und dem festgelegten oder theoretisch richtigen Wert oder Zustand

3.4.15
Ereignis
(en: event)
Vorgang einer Änderung von Zuständen

3.4.16
Speicherverwaltungseinheit des Feldbusses
(en: fieldbus memory management unit)
Funktion, die eine oder mehrere Korrespondenzen zwischen logischen Adressen und dem physischen Speicher aufbaut

3.4.17
Instanz der Speicherverwaltungseinheit des Feldbusses
(en: fieldbus memory management unit entity)
einzelnes Element der Speicherverwaltungseinheit des Feldbusses: eine Korrespondenz zwischen einem kohärenten logischen Adressraum und einem kohärenten physischen Speicherort

3.4.18
Full-Slave
(en: full slave)
Slave-Gerät, das sowohl die physische als auch die logische Adressierung von Daten unterstützt

3.4.19
Schnittstelle
(en: interface)
gemeinsam genutzte Grenze zwischen zwei funktionalen Einheiten, die durch funktionale Merkmale, Signalmerkmale oder andere Merkmale, soweit zutreffend, festgelegt ist

3.4.20
Master
(en: master)
Gerät, das die Datenübertragung auf dem Netzwerk steuert und den Medienzugriff der Slave-Stationen durch Senden von Nachrichten veranlasst und das die Schnittstelle zum Steuerungssystem darstellt

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3.4.21
Zuordnung
(en: mapping)
Verbindung zwischen zwei Objekten derart, dass ein Objekt ein Teil des anderen Objekts ist

3.4.22
Medium
(en: medium)
Kabel, Lichtwellenleiter oder andere Einrichtung, wodurch Kommunikationssignale zwischen zwei oder mehr Punkten übertragen werden

Anmerkung 1 zum Begriff: „Medien“ wird als die Pluralform von Medium verwendet.

3.4.23
Nachricht
(en: message)
geordnete Folge von Oktetten für die Übermittlung von Informationen

Anmerkung 1 zum Begriff: Üblicherweise für die Übermittlung von Informationen zwischen Peers auf der Anwendungsschicht verwendet.

3.4.24
Netzwerk
(en: network)
Menge von Knoten, die über ein bestimmtes Kommunikationsmedium miteinander verbunden sind, einschließlich jeglicher zwischengeschalteter Repeater, Bridges, Router und Gateways unterer Schichten

3.4.25
Knoten
(en: node)
Endpunkt eines Verbindungszweigs in einem Netzwerk oder Punkt, an dem zwei oder mehrere Verbindungszweige aufeinandertreffen

[QUELLE: IEC 61158-2, 3.1.31, modifiziert, mit einigen Anpassungen hinsichtlich der Formulierung]

3.4.26
Objekt
(en: object)
abstrakte Darstellung einer bestimmten Komponente innerhalb eines Gerätes

Anmerkung 1 zum Begriff: Ein Objekt kann sein:

1) eine abstrakte Darstellung des Vermögens eines Gerätes. Objekte können aus einigen oder aus allen der folgenden Komponenten bestehen:
   a) Daten (Informationen, die sich im Laufe der Zeit ändern);
   b) Konfiguration (Parameter für das Verhalten);
   c) Methoden (Dinge, die mithilfe der Daten und der Konfiguration durchgeführt werden können).
2) eine Zusammenstellung zugehöriger Daten (in Form von Variablen) und Methoden (Verfahren) für Operationen mit diesen Daten, die eine klar definierte Schnittstelle und ein klar definiertes Verhalten aufweisen.

3.4.27
Prozessdaten
(en: process data)
Datenobjekt, das Anwendungsobjekte enthält, die dazu vorgesehen sind, zu Verarbeitungszwecken zyklisch oder azyklisch übertragen zu werden

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3.4.28
Server
(en: server)
Objekt, das einem anderen (Client-)Objekt Dienste bereitstellt

3.4.29
Dienst
(en: service)
Operation oder Funktion, die ein Objekt und/oder eine Objektklasse auf Anforderung eines anderen Objekts und/oder einer anderen Objektklasse hin ausführt

3.4.30
Slave
(en: slave)
DL-Instanz, die nur nach Initiierung durch den vorausgehenden Slave oder den Master auf das Medium zugreift

3.4.31
Sync-Manager
(en: sync manager)
Zusammenstellung von Steuerelementen zur Koordinierung des Zugriffs auf gleichzeitig verwendete Objekte

3.4.32
Sync-Manager-Kanal
(en: sync manager channel)
einzelne Steuerelemente zur Koordinierung des Zugriffs auf gleichzeitig verwendete Objekte

3.4.33
Switch
(en: switch)
MAC-Bridge nach der Definition in IEEE 802.1D

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EUROPEAN STANDARD

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English Version

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

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

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

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

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European foreword

The text of document 65C/946/FDIS, future edition 4 of IEC 61158-4-12, prepared by SC 65C "Industrial networks" of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61158-4-12:2019.

The following dates are fixed:

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

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

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The text of the International Standard IEC 61158-4-12:2019 was approved by CENELEC as a European Standard without any modification.

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

IEC 61131-2	NOTE	Harmonized as EN 61131-2.
IEC 61131-3	NOTE	Harmonized as EN 61131-3.
IEC 61158-1	NOTE	Harmonized as EN 61158-1.
IEC 61158-2:2014	NOTE	Harmonized as EN 61158-2:2014 (not modified).
IEC 61158-5-12:2019	NOTE	Harmonized as EN IEC 61158-5-12:2019 (not modified).
IEC 61158-6-12	NOTE	Harmonized as EN 61158-6-12.
IEC 61784-1	NOTE	Harmonized as EN 61784-1.
IEC 61784-2	NOTE	Harmonized as EN 61784-2.

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

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

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

Publication	Year	Title	EN/HD	Year
IEC 61158-3-12	2019	Industrial communication networks - Fieldbus specifications - Part 3-12: Data-link layer service definition - Type 12 elements	EN IEC 61158-3-12	2019
IEC 61588	-	Precision clock synchronization protocol for networked measurement and control systems		-
ISO/IEC 7498-1	-	Information technology - Open Systems Interconnection - Basic reference model: The basic model		-
ISO/IEC 7498-3	-	Information technology - Open Systems Interconnection - Basic reference model: Naming and addressing		-
ISO/IEC 9899	-	Information technology - Programming languages - C		-
ISO/IEC 10731	-	Information technology - Open Systems Interconnection - Basic Reference Model - Conventions for the definition of OSI services		-
ISO/IEC/IEEE 8802-3	-	Standard for Ethernet	-	-
IEEE Std 802.1Q	-	IEEE Standard for Local and Metropolitan Area Networks – Bridges and bridged networks		-
IETF RFC 768	-	User Datagram Protocol	-	-
IETF RFC 791	-	Internet protocol DARPA internet program protocol specification		-

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INTRODUCTION

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

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

a) as a guide for implementors and designers;

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

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

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

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

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

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning Type 12 elements and possibly other types given as follows:

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

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

The holder of these patent rights has assured the IEC that he/she is willing to negotiate licences either free of charge or under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of these patent rights is registered with IEC. Information may be obtained from:

[BE]: Beckhoff Automation GmbH
Eiserstraße 5
33415 Verl,
Germany

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

ISO (www.iso.org/patents) and IEC (http://patents.iec.ch) maintain on-line databases of patents relevant to their standards. Users are encouraged to consult the databases for the most up to date information concerning patents.

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

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

1 Scope

1.1 General

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

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

a) in a synchronously-starting cyclic manner, and

b) in a cyclic or acyclic asynchronous manner, as requested each cycle by each of those data-link entities.

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

1.2 Specifications

This document specifies

a) procedures for the transfer of data and control information from one data-link user entity to one or more user entity;

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

1.3 Procedures

The procedures are defined in terms of

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

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

c) the interactions between a DLS-provider and the MAC services of ISO/IEC/IEEE 8802-3.

1.4 Applicability

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

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

1.5 Conformance

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

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2 Normative references

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

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

IEC 61158-3-12:2019, *Industrial communication networks – Fieldbus specifications – Part 3-12: Data-link layer service definition – Type 12 elements*

IEC 61588, *Precision clock synchronization protocol for networked measurement and control systems*

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

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

ISO/IEC/IEEE 8802-3, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet*

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

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

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

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

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

3 Terms, definitions, symbols, abbreviations and conventions

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

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

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

3.1 Reference model terms and definitions

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

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

3.2 Service convention terms and definitions

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

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3.2.1 asymmetrical service

**3.2.2 confirm (primitive);
requestor.deliver (primitive)**

3.2.3 deliver (primitive)

**3.2.4 DL-service-primitive;
primitive**

3.2.5 DL-service-provider

3.2.6 DL-service-user

**3.2.7 indication (primitive)
acceptor.deliver (primitive)**

**3.2.8 request (primitive);
requestor.submit (primitive)**

3.2.9 requestor

**3.2.10 response (primitive);
acceptor.submit (primitive)**

3.2.11 submit (primitive)

3.2.12 symmetrical service

3.3 Common terms and definitions

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

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

3.3.1
frame
denigrated synonym for DLPDU

3.3.2
group DL-address
DL-address that potentially designates more than one DLSAP within the extended link

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

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

3.3.3
node
single DL-entity as it appears on one local link

3.3.4
receiving DLS-user
DL-service user that acts as a recipient of DLS-user-data

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

3.3.5
sending DLS-user
DL-service user that acts as a source of DLS-user-data

3.4 Additional Type 12 definitions

3.4.1
application
function or data structure for which data is consumed or produced

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

3.4.2
application objects
multiple object classes that manage and provide a run time exchange of messages across the network and within the network device

3.4.3
basic slave
slave device that supports only physical addressing of data

3.4.4
bit
unit of information consisting of a 1 or a 0

Note 1 to entry: This is the smallest data unit that can be transmitted.

3.4.5
client
<object> object which uses the services of another (server) object to perform a task

3.4.6
client
<message> initiator of a message to which a server reacts

3.4.7
connection
logical binding between two application objects within the same or different devices

3.4.8
cyclic
events which repeat in a regular and repetitive manner

3.4.9
cyclic redundancy check
CRC
residual value computed from an array of data and used as a representative signature for the array

3.4.10
data
generic term used to refer to any information carried over a Fieldbus

3.4.11
data consistency
means for coherent transmission and access of the input- or output-data object between and within client and server

3.4.12
device
physical entity connected to the fieldbus composed of at least one communication element (the network element) and which may have a control element and/or a final element (transducer, actuator, etc.)

[SOURCE: IEC 61158-2, 3.1.13]

3.4.13
distributed clocks
method to synchronize slaves and maintain a global time base

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3.4.14
error
discrepancy between a computed, observed or measured value or condition and the specified or theoretically correct value or condition

3.4.15
event
instance of a change of conditions

3.4.16
fieldbus memory management unit
function that establishes one or several correspondences between logical addresses and physical memory

3.4.17
fieldbus memory management unit entity
single element of the fieldbus memory management unit: one correspondence between a coherent logical address space and a coherent physical memory location

3.4.18
full slave
slave device that supports both physical and logical addressing of data

3.4.19
interface
shared boundary between two functional units, defined by functional characteristics, signal characteristics, or other characteristics as appropriate

3.4.20
master
device that controls the data transfer on the network and initiates the media access of the slaves by sending messages and that constitutes the interface to the control system

3.4.21
mapping
correspondence between two objects in that way that one object is part of the other object

3.4.22
medium
cable, optical fibre, or other means by which communication signals are transmitted between two or more points

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

3.4.23
message
ordered series of octets intended to convey information

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

3.4.24
network
set of nodes connected by some type of communication medium, including any intervening repeaters, bridges, routers and lower-layer gateways

3.4.25
node
end-point of a link in a network or a point at which two or more links meet

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

3.4.26
object
abstract representation of a particular component within a device

Note 1 to entry: An object can be

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

3.4.27
process data
data object containing application objects designated to be transferred cyclically or acyclically for the purpose of processing

3.4.28
server
object which provides services to another (client) object

3.4.29
service
operation or function than an object and/or object class performs upon request from another object and/or object class

3.4.30
slave
DL-entity accessing the medium only after being initiated by the preceding slave or the master

3.4.31
Sync manager
collection of control elements to coordinate access to concurrently used objects

3.4.32
Sync manager channel
single control elements to coordinate access to concurrently used objects

3.4.33
switch
MAC bridge as defined in IEEE 802.1D

3.5 Common symbols and abbreviations

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

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

3.6 Additional Type 12 symbols and abbreviations

AL	Application layer
AoE	Automation Device Specification (ADS) over Type 12
APRD	Auto increment physical read
APRW	Auto increment physical read write
APWR	Auto increment physical write
ARMW	Auto increment physical read multiple write
BRD	Broadcast read
BRW	Broadcast read write
BWR	Broadcast write
CAN	Controller area network
CoE	CAN application protocol over Type 12 services
CSMA/CD	Carrier sense multiple access with collision detection
DC	Distributed clocks
DCSM	DC state machine
DHSM	(DL) PDU handler state machine
Type 12	Prefix for DL services and protocols
E²PROM	Electrically erasable programmable read only memory
EoE	Ethernet tunneled over Type 12 services
ESC	Type 12 slave controller
FCS	frame check sequence

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

3.7 Conventions

3.7.1 General concept

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

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

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3.7.2 Abstract syntax conventions

The DL syntax elements related to PDU structure are described as shown in the example of Table 1.

Frame part denotes the element that will be replaced by this reproduction.

Data field is the name of the elements.

Data Type denotes the type of the terminal symbol.

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

Table 1 – PDU element description example

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

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

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

Figure 1 – Type description example

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

Parameter describes a single element of the attribute.

Physical address denotes the location in physical address space.

Data Type denotes the type of this element.

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

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

Table 2 – Example attribute description

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

3.7.3 Convention for the encoding of reserved bits and octets

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

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

3.7.4 Conventions for the common coding s of specific field octets

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

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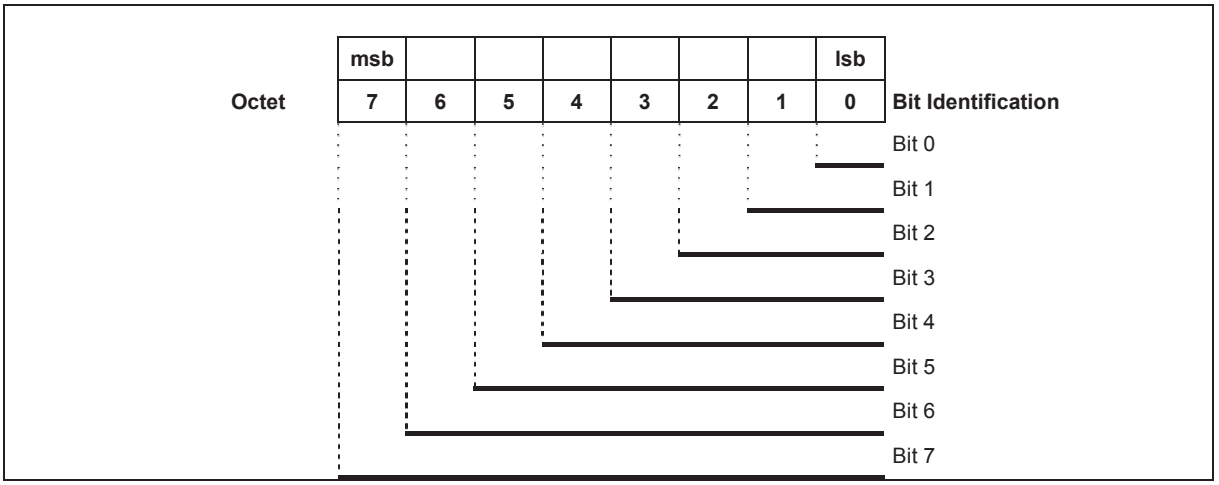


Figure 2 – Common structure of specific fields

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

EXAMPLE Description and relation for the specific field octet

Bit 0: reserved.

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

Bit 4-7: shall always set to one.

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

(msb) Bit 7 = 1,

Bit 6 = 1,

Bit 5 = 1,

Bit 4 = 1,

Bit 3 = 0,

Bit 2 = 1,

Bit 1 = 0,

(lsb) Bit 0 = 0.

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

3.7.5 State machine conventions

The protocol sequences are described by means of State Machines.

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

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

– The first column contains the name of the transition.

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

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

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

Table 3 – State machine description elements

#	Current state	Event /Condition => Action	Next state

Table 4 – Description of state machine elements

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

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

Table 5 – Conventions used in state machines

Convention	Meaning
=	Value of an item on the left is replaced by value of an item on the right. If an item on the right is a parameter, it comes from the primitive shown as an input event.
axx	A parameter name if a is a letter. EXAMPLE Identifier = reason means value of a 'reason' parameter is assigned to a parameter called 'Identifier.'
"xxx"	Indicates fixed visible string. EXAMPLE Identifier = "abc" means value "abc" is assigned to a parameter named 'Identifier.'
nnn	if all elements are digits, the item represents a numerical constant shown in decimal representation
0xnn	if all elements nn are digits, the item represents a numerical constant shown in hexadecimal representation
==	A logical condition to indicate an item on the left is equal to an item on the right.
<	A logical condition to indicate an item on the left is less than the item on the right.

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Convention	Meaning
>	A logical condition to indicate an item on the left is greater than the item on the right.
!=	A logical condition to indicate an item on the left is not equal to an item on the right.
&&	Logical "AND"
||	Logical "OR"
!	Logical "NOT"
+ – * /	Arithmetic operators
;	Separator of expressions

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

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

4 Overview of the DL-protocol

4.1 Operating principle

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

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

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

4.2 Topology

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

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

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

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

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4.3 Frame processing principles

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

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

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

e) directly in the data area of the Ethernet frame,

f) within the data section of a UDP datagram transported via IP.

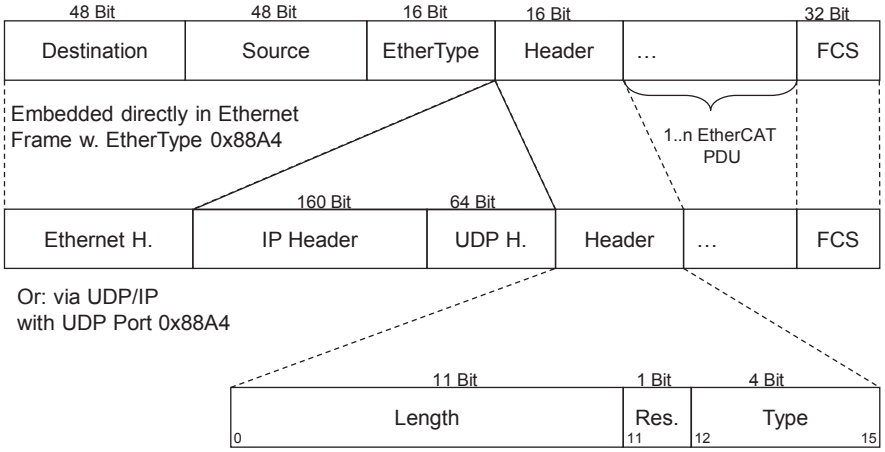


Figure 3 – Frame structure

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

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

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

4.4 Data-link layer overview

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

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

Therefore the slave nodes may also support logical address mapping. The process data can be inserted anywhere within a logical address space. If a Type 12 PDU is sent that contains read or write services for a

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certain process image area located at the corresponding logical address, instead of addressing a particular node, the nodes insert the data at or extract the data from the right place within the process data, as noted in Figure 4.

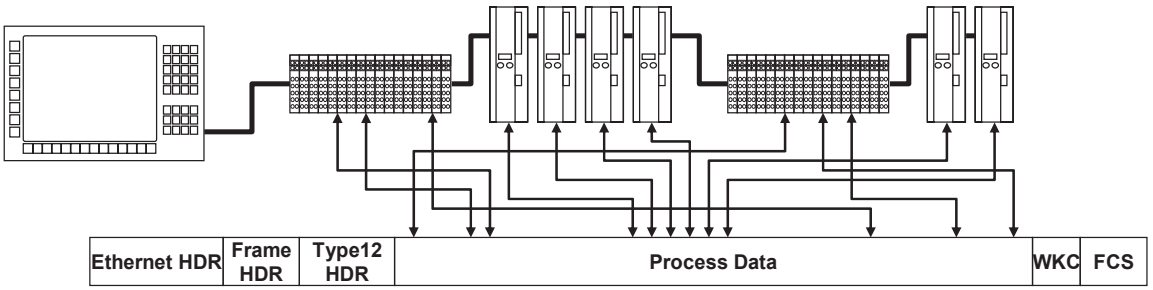


Figure 4 – Mapping of data in a frame

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

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

4.5 Error detection overview

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

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

4.6 Node reference model

4.6.1 Mapping onto OSI basic reference model

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

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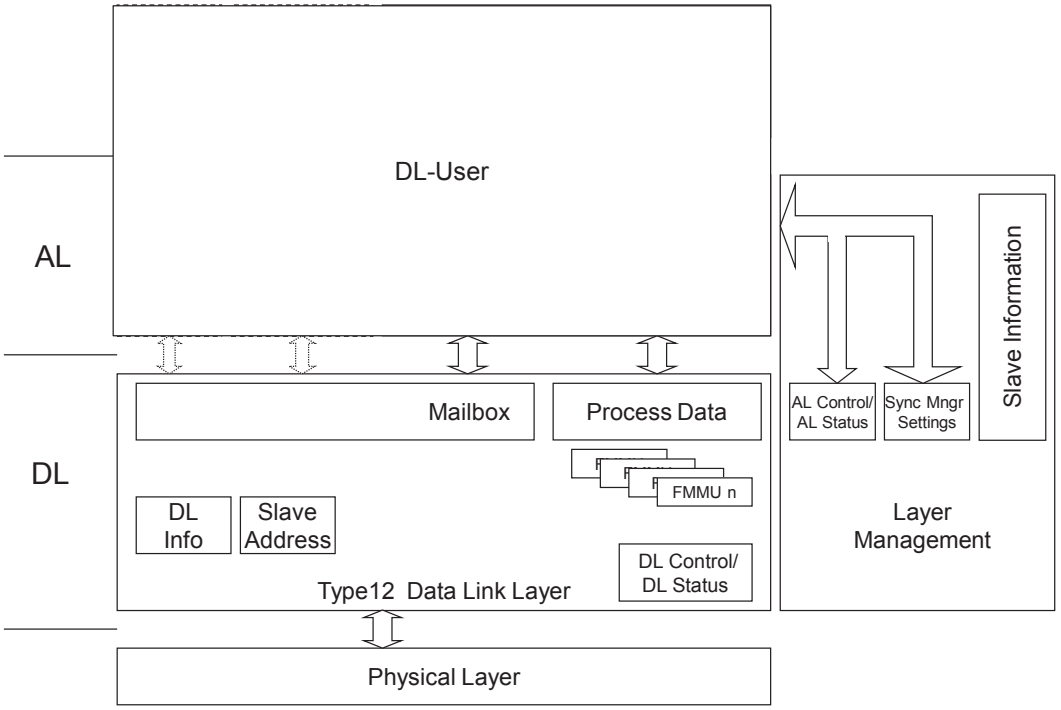


Figure 5 – Slave node reference model

4.6.2 Data-link Layer features

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

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

4.7 Operation overview

4.7.1 Relation to ISO/IEC/IEEE 8802-3

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

4.7.2 Frame structure

A Type 12 Ethernet frame contains one or several Type 12 PDUs (as shown in Figure 6), each addressing individual devices and/or memory areas. The Type 12 frame is recognized by the combination of the EtherType 0x88A4[1] and the corresponding Type 12 frame header or, when transported via UDP/IP according to IETF RFC 791/IETF RFC 768 (as shown in Figure 7) by the Destination UDP port 34980=0x88A4[2] and the Type 12 frame header. Fragmentation of IP packets will be ignored. The UDP checksum shall be set to 0 by

---

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

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

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Slaves and could be ignored. No check on IP type of service, IP header checksum, IP packet length and UDP length is required.

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

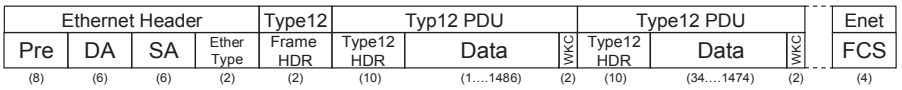


Figure 6 – Type 12 PDUs embedded in Ethernet frame

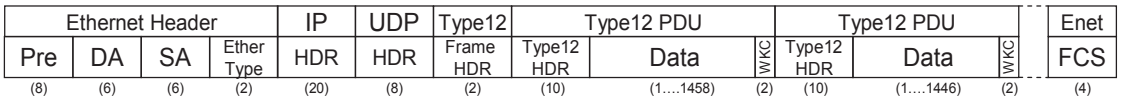


Figure 7 – Type 12 PDUs embedded in UDP/IP

5 Frame structure

5.1 Frame coding principles

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

5.2 Data types and encoding rules

5.2.1 General description of data types and encoding rules

To be able to exchange meaningful data, the format of this data and its meaning have to be known by the producer and consumer(s). This specification models this by the concept of data types.

The encoding rules define the representation of values of data types and the transfer syntax for the representations. Values are represented as bit sequences. Bit sequences are transferred in sequences of octets (bytes). For numerical data types the encoding is little endian style as shown in Table 6.

The data types and encoding rules shall be valid for the DL services and protocols as well as for the AL services and protocols specified. The encoding rules for the Ethernet frame are specified in ISO/IEC/IEEE 8802-3. The DLSDU of Ethernet is an octet string. The transmission order within octets depends upon MAC and PhL encoding rules.

5.2.2 Transfer syntax for bit sequences

For transmission across Type 12 DL a bit sequence is reordered into a sequence of octets. Hexadecimal notation is used for octets as specified in ISO/IEC 9899. Let $b = b0...bn\text{-}1$ be a bit sequence. Denote k a non-negative integer such that $8(k - 1) < n \leq 8k$. Then b is transferred in k octets assembled as shown in Table 6. The bits bi, $i \geq n$ of the highest numbered octet are do not care bits.

Octet 1 is transmitted first and octet k is transmitted last. Hence the bit sequence is transferred as follows across the network (transmission order within an octet is determined by ISO/IEC/IEEE 8802-3):

$b7, b6, ..., b0, b15, ..., b8, ...$

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Table 6 – Transfer Syntax for bit sequences

Octet number	1.	2.	k.
	b7 .. b0	b15 .. b8	b8k –1 .. b8k -8

EXAMPLE

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

The bit sequence b = b0 .. b9 = 0011 1000 01_b represents an Unsigned10 with the value 0x21C and is transferred in two octets: First 0x1C and then 0x02.

5.2.3 Unsigned Integer

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

b = *b*0 ...*b*n-1

is assigned the value

Unsignedn(b) = bn-1×2n-1+ ...+ b1×21 + b0×20

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

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

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

Table 7 – Transfer syntax for data type Unsignedn

octet number	1.	2.	3.	4.	5.	6.	7.	8.
Unsigned8	b7..b0							
Unsigned16	b7..b0	b15..b8						
Unsigned32	b7..b0	b15..b8	b23..b16	b31..b24				
Unsigned64	b7..b0	b15..b8	b23..b16	b31..b24	b39..b32	b47..b40	b55..b48	b63..b56

5.2.4 Signed Integer

Data of basic data type Integern has values in the integers. The value range is from -2*n*-1 to 2*n*-1-1. The data is represented as bit sequences of length *n*. The bit sequence

b = *b*0 .. *bn*-1

is assigned the value

Integern(*b*) = *bn*-2×2*n*-2 + ...+ *b*1×21 + *b*0×20 if *bn*-1 = 0

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and, performing two's complement arithmetic,

Integern(*b*) = – Integern(^b) – 1 if *bn*-1 = 1

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

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

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

Table 8 – Transfer syntax for data type Integern

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

5.2.5 Octet String

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

ARRAY [length] OF Unsigned8 OctetString*length*

5.2.6 Visible String

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

Unsigned8 VISIBLE_CHAR

ARRAY [length] OF VISIBLE_CHAR VisibleString*length*

There is no 0x0 necessary to terminate the string.

5.3 Ethernet DLPDU structure

5.3.1 Type 12 frame inside an Ethernet frame

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

Table 9 – Type 12 frame inside an Ethernet frame

Frame part	Data field	Data type	Value/description
Ethernet	Dest MAC	BYTE[6]	Destination MAC Address as specified in ISO/IEC/IEEE 8802-3
	Src MAC	BYTE[6]	Source MAC Address as specified in ISO/IEC/IEEE 8802-3
(optional)	VLAN Tag	BYTE[4]	0x81, 0x00 and two bytes Tag Control Information as specified in IEEE 802.1Q
	Ether Type	BYTE[2]	0x88, 0xA4 (Type 12)

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	Type 12 frame		specified in 5.3.3
	Padding	BYTE[n]	shall be inserted if DL PDU is shorter than 64 octets as specified in ISO/IEC/IEEE 8802-3
Ethernet FCS	FCS	Unsigned32	Standard Ethernet Checksum coding as specified in ISO/IEC/IEEE 8802-3

5.3.2 Type 12 frame inside a UDP datagram

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

Table 10 – Type 12 frame inside an UDP PDU

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

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Frame part	Data field	Data type	Value/description
Ethernet FCS	FCS	Unsigned32	Standard Ethernet Checksum coding as specified in ISO/IEC/IEEE 8802-3

NOTE 1 IP packet structure and coding requirements are as specified in IETF RFC 791.

NOTE 2 The ordering of octets in multi-octet values is encoded differently in IETF protocols (see IETF RFC 768 and RFC 791) than it is within the Type 12 DL-protocol.

5.3.3 Type 12 frame structure

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

Table 11 – Type 12 frame structure containing Type 12 PDUs

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

Table 12 – Type 12 frame structure containing network variables

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

Table 13 – Type 12 frame structure containing mailbox

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

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5.4 Type 12 DLPDU structure

5.4.1 Read

5.4.1.1 Overview

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

5.4.1.2 Auto increment physical read (APRD)

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

Table 14 – Auto increment physical read (APRD)

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

CMD

The parameter Command shall contain the service command.

IDX

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

ADP

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

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

ADO

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

LEN

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

C

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

NEXT

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

IRQ

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

DATA

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

WKC

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

5.4.1.3 Configured address physical read (FPRD)

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

Table 15 – Configured address physical read (FPRD)

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

CMD

The parameter Command shall contain the service command.

IDX

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

ADP

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

ADO

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

LEN

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

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C

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

NEXT

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

IRQ

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

DATA

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

WKC

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

5.4.1.4 Broadcast read (BRD)

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

Table 16 – Broadcast read (BRD)

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

CMD

The parameter Command shall contain the service command.

IDX

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

ADP

This parameter shall be incremented by one at each slave.

ADO

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

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