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Nationaler Anhang NA
(informativ)

Begriffe und Abkürzungen

Reihenfolge und Inhalt der folgenden Begriffe sind identisch mit denen in Abschnitt Begriffe der englischen Fassung.

3 Begriffe und Abkürzungen

3.1 Begriffe aus anderen Normen

Für die Anwendung dieses Dokuments gelten die Begriffe nach ECSS-S-ST-00-01.

3.2 Spezifische Begriffe für die vorliegende Norm

3.2.1
Annahmezeitfenster
Zeitintervall, in dem der Empfang des zu einer VL-ID gehörenden Frames erwartet wird

3.2.2
Bandwidth Allocation Gap
BAG
minimale Verzögerung zwischen zwei aufeinanderfolgenden Rate-Constrained-Frames, die zum gleichen Sendeintervall gehören

[QUELLE: ARINC 664 Teil 7]

3.2.3
Best-Effort-Traffic
Standard-Ethernet-Frame, der weder **kritischer Verkehr** noch flussgesteuerter Verkehr ist

Anmerkung 1 zum Begriff: Ein Best-Effort-Frame oder -Traffic, wie nach Norm [IEEE 802.3] festgelegt.

3.2.4
Rundsendung
Übertragung eines Ethernet-Frames von einem Sender zu allen Empfängern

3.2.5
Cluster
Ethernet-Netzwerk, das aus Knoten besteht, die durch das zeitgesteuerte Ethernet-Protokoll miteinander synchronisiert sind

3.2.6
Kompressionsmaster
Rolle eines Elements des Clusters, das Protokoll-Steuer-Frames (PCFs) von den Synchronisationsmastern sammelt und komprimiert und sie in einem Timing-Algorithmus verwendet, bevor sie an die konfigurierten Synchronisationsmaster und Synchronisationsclients zurückgesendet werden, um für die Synchronisation verwendet zu werden

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3.2.7
kritischer Verkehr
CT, en: critical traffic
Fluss von kritischen Traffic-Frames, wobei bei jedem Frame die 32 Bits der höchsten Wertigkeit auf den kritischen Traffic-Marker gesetzt sind

Anmerkung 1 zum Begriff: Kritischer Traffic-Marker ist der Wert der 32 Bits der höchsten Wertigkeit der MAC-Zieladresse, der einen Frame als kritischen Verkehr identifiziert.

3.2.8
Gerät
Element eines Ethernet-Netzwerks oder ein Element, das mit einem Ethernet-Knoten verbunden ist

Anmerkung 1 zum Begriff: Ein Device kann entweder ein Switch oder ein Endsystem oder ein Host-Computer sein. Ein Device unterstützt nicht unbedingt RC- oder TT- oder BE-Traffic.

3.2.9
Endsystem
Netzwerkkomponente, die dem Host-Device eine Schnittstelle zum Netzwerk bereitstellt

Anmerkung 1 zum Begriff: Jedes Host-Device verwendet eine Endsystem-Schnittstelle, um einen sicheren und zuverlässigen Datenaustausch mit anderen Host-Devices sicherzustellen.

3.2.10
flussgesteuerter Verkehr
Folge von Ethernet-Paketen von einem Sender zu einem oder mehreren Empfängern

Anmerkung 1 zum Begriff: Eine flussgesteuerter Verkehr, wie in [RFC 3697] festgelegt.

3.2.11
Frame
Teil eines Pakets

Anmerkung 1 zum Begriff: Die folgenden Frame-Typen werden in diesem Dokument verwendet:

— Best-Effort-Frame: Basic-Frame;

— Kritischer Traffic-Frame: Rate-Constrained-(RC)-Frame; Protokoll-Steuer-Frame (ist ein RC-Frame); zeitgesteuerter Frame (TT, en: Time-Triggered).

Anmerkung 2 zum Begriff: Ein Beispiel für ein Paket ist in Bild 3-1 angegeben.

3.2.12
global verwaltet
eindeutige MAC-Adresse, die der Netzwerkschnittstellenkarte vom Hersteller zugewiesen wurde

3.2.13
Verknüpfung
physikalische Verbindungen zwischen Knoten in einem Netzwerk, die die Übertragung von Frames zwischen ihnen ermöglichen

3.2.14
lokal verwaltet
eindeutige MAC-Adresse, die der Netzwerkschnittstellenkarte lokal zugewiesen wurde

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3.2.15
Multicast
Übertragung eines Ethernet-Frames von einem Sender zu mehreren Empfängern

3.2.16
Knoten
Element eines Ethernet-Netzwerks

Anmerkung 1 zum Begriff: Ein Knoten kann entweder ein Switch oder ein Endsystem sein. Ein Knoten unterstützt nicht unbedingt RC- und TT-Traffic, allerdings mindestens BE.

3.2.17
Paket
vollständige Ethernet-Nachricht, einschließlich der Header-Information, bestehend aus der Präambel und dem Start-Frame-Delimiter

Anmerkung 1 zum Begriff: Das Ethernet-Paket ist festgelegt in 1000Base-X PCS [IEEE 802.3] Abschnitt 36 [2], Sektion 1/Sektion 3 „Media Access Control (MAC) frame and packet specifications“. Der Aufbau ist in Bild 3-1 angegeben.

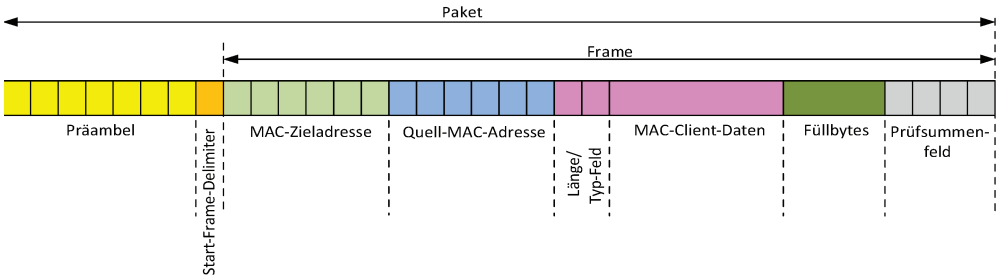


Bild 3-1 — Aufbau eines Pakets

3.2.18
Protokoll-Steuer-Frame
Standard-Ethernet-Frame, dessen Ethernet-Typ-Feld auf 0x891D gesetzt ist, das vom Synchronisationsprotokoll verwendet wird

[QUELLE: SAE AS6802]

3.2.19
Rastergranularität
Zeitachse, auf der Scheduling-Ereignisse platziert werden

3.2.20
Rate-Constrained
garantierter Bandbreitenverkehr, wie von der Norm festgelegt

[QUELLE: ARINC 664 Teil 7]

3.2.21
Zeitplan-Tabelle
Zeitplan der Übertragungs- und Empfangsereignisse für kritischen Verkehr

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3.2.22
Switch
Hardware-Gerät, das mehrere Endsysteme oder Switches mit einem Netzwerk verbindet

Anmerkung 1 zum Begriff: Ein Switch arbeitet auf Layer 2 der Ethernet-Spezifikation und verfügt über zwei verschiedene Möglichkeiten zur Paketvermittlung zwischen den verschiedenen Geräten, die an seine Ethernet-Ports angeschlossen sind, statisches und dynamisches Switching. Die statische Paketvermittlung arbeitet nach einer definierten statischen Switching-Tabelle. Dynamisches Switching beschreibt einen automatisierten Weiterleitungspfad für eine gegebene MAC-Zieladresse basierend auf der aktuellen Netzwerkarchitektur.

3.2.23
Synchronisations-Client
Rolle eines Elements des Clusters, das von Kompressionsmastern empfangene Protokoll-Steuer-Frames (PCFs) zu Synchronisationszwecken verwendet, ohne aktiv am Netzwerksynchronisationsprozess teilzunehmen

3.2.24
Synchronisationsmaster
Rolle eines Elements des Clusters, das Protokoll-Steuer-Frames (PCFs) generiert, an die Kompressionsmaster überträgt und von den Kompressionsmastern empfangene PCFs zu Synchronisationszwecken verwendet und aktiv am Netzwerksynchronisationsprozess teilnimmt

3.2.25
Synchronisationspräzision
ungünstigster Fall, wenn der lokale Taktgeber zwischen zwei korrekten Endsystemen oder Switches im System versetzt ist

Anmerkung 1 zum Begriff: Die Berechnung ist in [SAE AS6802], 3.2, angegeben.

3.2.26
zeitgesteuerter Frame
kritischer Verkehr (CT)-Frame, der zu vordefinierten Zeiten über das Netzwerk gesendet wird und Vorrang vor allen anderen Frame-Typen hat, mit Ausnahme von Protokoll-Steuer-Frames

3.2.27
Unicast
Übertragung eines Ethernet-Frames von einem Sender zu einem Empfänger

3.2.28
Virtual Link
VL
logischer unidirektionaler Verbindungspfad zwischen einem Knoten zu einem oder mehreren Knoten

[QUELLE: ARINC 664 Teil 7]

3.2.29
Virtual-Link-Identifier
VLID
16 Bits der niedrigsten Wertigkeit der MAC-Zieladresse eines kritischen Verkehrs-Frames

Anmerkung 1 zum Begriff: Entsprechend der Definition der Norm [ARINC 664 Teil 7] identifiziert die VLID eindeutig eine Multicast-Gruppe mit einem dedizierten Absender der Nachricht und einer Reihe von Empfängern.

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3.3 Abkürzungen

Für die Anwendung dieser Norm gelten die Abkürzungen nach ECSS-S-ST-00-01 und die folgenden Abkürzungen:

Abkürzung	Bedeutung
API	Anwendungsprogramm-Schnittstelle (en: Application Programming Interface)
ARINC	Aeronautical Radio Incorporated
BAG	Bandbreitenzuweisungslücke (en: Bandwidth Allocation Gap)
BE	Auslieferung nach bestem Bemühen (en: best effort)
CD	Kollisionserkennung (en: Collision Detection)
CM	Kompressionsmaster (en: Compression Master)
CRC	zyklische Blockprüfung (en: cyclic redundancy check)
CSMA	Mehrfachzugriff mit Trägerprüfung (en: Carrier Sense Multiple Access)
CT	kritischer Verkehr (en: critical traffic)
DLL	Sicherungsschicht (en: Data Link Layer)
ECSS	Europäische Kooperation für Raumfahrtnormung (en: European Cooperation for Space Standardization)
EMC	elektromagnetische Verträglichkeit (en: electromagnetic compatibility)
ES	Endsystem (en: End System)
ESCC	Europäische Weltraumkomponenten-Koordination (en: European Space Components Coordination)
FCS	Prüfsummenfeld (en: frame check sequence)
FDIR	Fehlererkennung, Isolierung und Wiederherstellung (en: failure detection, isolation and recovery)
FT	Fehlertoleranz (en: Fault Tolerant)
Gbps	Gigabit je Sekunde (en: giga bit per second)
GMII	medienunabhängige Gigabit-Schnittstelle (en: gigabit media independent interface)
GND	Erdung
H/W	Hardware
IC	Integritätsprüfung (en: Integrity Checking)
ICMP	Internet Control Message Protocol
ID	Identifikationsnummer
IEEE	Institute of Electrical and Electronics Engineers
IFG	Interframe-Gap
IHL	Header-Länge (en: Internet Header Length)
IP	IP-Protokoll (en: Internet Protocol)

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Abkürzung	Bedeutung
IP	geistiges Eigentum (en: Intellectual Property)
ISO	Internationale Organisation für Normung
LAN	lokales Netzwerk (en: Local Area Network)
LLC	Logic Link Control
LVDS	Low Voltage Differential Signalling
MAC	Medienzugriffssteuerung (en: Media Access Control)
Mbps	Megabit je Sekunde
MIB	Verwaltungsinformationsbasis (en: Management Information Base)
MII	medienunabhängige Schnittstelle (en: media independent interface)
OSI	Verbindung offener Systeme (en: open system interconnection)
PCB	Leiterplatte (printed circuit board)
PCF	Protokoll-Steuer-Frame (en: Protocol Control Frame)
PCS	Unterschicht für physikalische Codierung (en: Physical Coding Sublayer)
PHY	Bitübertragungsschicht (en: Physical Layer)
PLS	Signalisierung der Bitübertragungsschicht (en: Physical Layer Signalling)
PMA	Teilschicht des physikalischen Medienzugangs (en: Physical Medium Attachment Sublayer)
PMD	unterste Teilschicht der Bitübertragungsschicht (en: Physical Medium Dependent Sublayer)
QoS	Dienstgüte (en: quality of service)
RC	Rate-Constraint
RM	Redundanz-Management (en: Redundancy Management)
SAE	Society of Automotive Engineers
SC	Synchronisations-Client (en: Synchronization Client)
SFD	Start-Frame-Delimiter
SM	Synchronisationsmaster
SN	Laufnummer (en: sequence number)
SNMP	einfaches Netzwerkverwaltungsprotokoll (en: Simple Network Management Protocol)
SW	Switch
TFTP	einfaches Dateiübertragungsprotokoll (en: Trivial File Transfer Protocol)
TT	zeitgesteuert (en: time-triggered)
UDP	Anwender-Datagramm-Protokoll (en: User Datagram Protocol)
VL	Virtual Link

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– Entwurf –

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

DRAFT
prEN 16603-50-16

February 2021

ICS

English version

Space engineering - Time triggered Ethernet

Ingénierie spatiale - Ethernet déclenché par le temps (TTE)

Raumfahrttechnik - Zeitgesteuertes Ethernet (TTE)

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

If this draft becomes a European Standard, CEN and 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.

This draft European Standard was established by CEN and CENELEC in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN and 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 Foreword

This document (prEN 16603-50-16:2021) has been prepared by Technical Committee CEN/CLC/TC 5 “Space”, the secretariat of which is held by DIN (Germany).

This document (prEN 16603-50-16:2021) originates from ECSS-E-ST-50-16C DIR1.

This document is currently submitted to the Enquiry.

This document has been developed to cover specifically space systems and will therefore have precedence over any EN covering the same scope but with a wider do-main of applicability (e.g. : aerospace).

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1 Scope

Using standard communication protocols for spacecraft communication links can provide interface compatibility between communication devices and components. Thus, it can improve the design and development process as well as integration and test activities at all levels and provide the potential of reusability across projects.

The aim of this space engineering standard is to define the interface services and to specify their corresponding network protocol elements for spacecraft using the Time-Triggered Ethernet data network. It also aims at defining requirements for the harmonisation of the physical interfaces and usage of the [IEEE 802.3] and [SAE AS6802] layer features.

This standard may be tailored for the specific characteristic and constraints of a space project in conformance with ECSS-S-ST-00.

Approach

The approach of the ECSS working group for defining this standard aims at identification of layers, services and functions of the typical Time-Triggered Ethernet communication network to ensure the use of the technology for various space projects. The standard aims at:

- Identifying Reference Architectures (Layers, Services, Functions and Elements of protocol) of typical Time-Triggered Ethernet communication network;
- Characterizing Services, Functions and Elements of Protocol of each Layer within identified Reference Architectures, using concrete project specifications;
- Define normative requirements rather than recommendations.

As far as possible, the defined communication requirements are extracted from the experience on existing spacecraft specifications.

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2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS System - Glossary of terms
	ARINC 664 part 2, 24 October 2018	Aircraft Data Network Part 2: Ethernet Physical and Data Link Layer Specification
	ARINC 664 part 7, 23 September 2009	Aircraft Data Network Part 2: Avionic Full-Duplex Switched Ethernet Network
	IEEE 802.3, 28 December 2012	Ethernet Standard
	SAE AS6802, November 2011	Time-triggered Ethernet
	RFC 768, 28 August 1980	User Datagram Protocol (UDP)
	RFC 791, September 1981	Internet Protocol (IP)
	RFC 792, September 1981	Internet Control Message Protocol (ICMP)
	RFC 1157, May 1990	A simple network management protocol (for SNMPv1)
	RFC 1350, July 1992	The TFTP Protocol (Revision 2)
	RFC 2349, May 1998	TFTP Timeout Interval and Transfer Size Options
	RFC 3697, March 2004	IPv6 Flow Label Specification

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3 Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply.

3.2 Terms specific to the present standard

3.2.1 acceptance window

timing interval in which the reception of the frame associated with a VL ID is expected

3.2.2 bandwidth allocation gap (BAG)

minimum delay between two consecutive Rate-Constrained frames belonging to the same sending interval

[ARINC 664 part 7]

3.2.3 best-effort traffic

standard Ethernet frame which is neither **critical traffic** nor flow controlled traffic

NOTE A Best-Effort frame or traffic as specified by the standard [IEEE 802.3].

3.2.4 broadcast

transmission of an Ethernet frame from one sender to all receivers

3.2.5 cluster

Ethernet network composed of nodes synchronized to each other by the time-triggered Ethernet protocol

3.2.6 compression master

role of an element of the cluster that collects protocol control frames (PCFs) from the synchronization masters and compresses uses them in a timing algorithm, compression, before sending them back to the configured synchronization masters and synchronization clients, to be used for synchronization purpose

3.2.7 critical traffic (CT)

flow of critical traffic frames, where each frame has the most significant 32 bits set to the critical traffic marker

NOTE Critical Traffic Marker is the value of the most significant 32 bits of the MAC Destination

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Address that identifies a frame as Critical Traffic.

3.2.8 device

element of an Ethernet network or an element connected to an Ethernet node

NOTE A device can be either a switch or an **end system** or a host computer. A device does not necessarily support RC or TT or BE traffic.

3.2.9 end system

network component which provides the host device an interface to the network

NOTE Each host device uses an End System interface to guarantee a secure and reliable data interchange with other host device.

3.2.10 flow controlled traffic

sequence of Ethernet packets from one sender to one or multiple receivers

NOTE A Flow controlled traffic as specified by [RFC 3697].

3.2.11 frame

part of a packet

NOTE 1 The following frame types are used throughout this document:

- Best-Effort frame: Basic Frame
- Critical Traffic frame: Rate-Constrained (RC) frame; Protocol Control Frame (is a RC frame); Time-Triggered (TT) frame

NOTE 2 Example of a packet is shown in Figure 3-1.

3.2.12 globally administered

unique MAC address assigned to the network interface card by the manufacturer

3.2.13 link

physical connections between nodes in a network providing the means for transferring frames between them

3.2.14 locally administered

unique MAC address assigned to the network interface card locally

3.2.15 multicast

transmission of an Ethernet frame from one sender to multiple receivers

3.2.16 node

element of an Ethernet network

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NOTE A node can be either a Switch or an End System. A node does not necessarily support RC and TT traffic but at least BE.

3.2.17 packet

complete Ethernet message including the header information consisting of the preamble and the start of frame delimiter

NOTE The Ethernet packet is specified in, 1000Base-X PCS, [IEEE 802.3] Clause 36 [2], section 1/section 3 ”Media Access Control (MAC) frame and packet specifications”. The structure is shown in Figure 3-1.

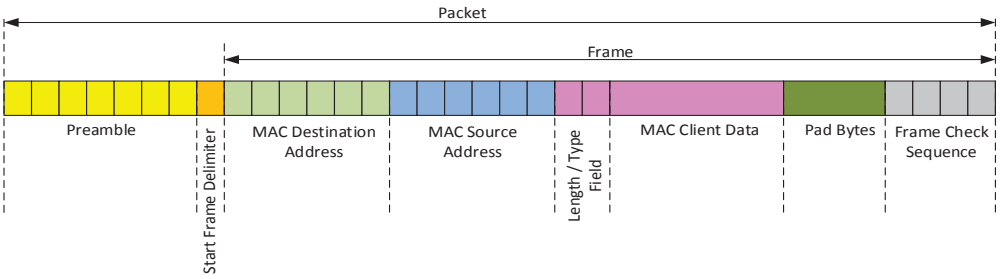


Figure 3-1: Structure of a Packet

3.2.18 protocol control frame

standard Ethernet frame whose Ethernet type field is set to 0x891D, which is used by the synchronization protocol

[SAE AS6802]

3.2.19 raster granularity

timeline on which scheduling events are placed

3.2.20 rate-constrained

guaranteed bandwidth traffic as specified by the standard

[ARINC 664 part 7]

3.2.21 schedule table

time schedule of transmission and reception events for critical traffic.

3.2.22 switch

hardware device that connects multiple End Systems or Switches to one network

NOTE A Switch works on Layer 2 of the Ethernet specification and has two different ways of packet switching between the different devices connected to its Ethernet ports which are static and dynamic switching. The static packet switching works according to a defined static switching table. Dynamic switching describes an

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automated forward path for a given MAC destination address based on the current network architecture.

3.2.23 synchronization client

role of an element of the cluster that consumes protocol control frames (PCFs) received from compression masters for synchronization purpose, without actively participating in the network synchronization process

3.2.24 synchronization master

role of an element of the cluster that generates protocol control frames (PCFs), transmits them to the compression masters, and consumes PCFs received from compression masters for synchronization purpose, actively participating in the network synchronization process

3.2.25 synchronization precision

worst case Local Clocks offset between any two correct End Systems or Switches in the system

NOTE The calculation is given in [SAE AS6802] paragraph 3.2.

3.2.26 time-triggered frame

Critical Traffic (CT) frame which is sent over the network at predefined times and take precedence over all other frames types, except for Protocol Control Frames

3.2.27 unicast

transmission of an Ethernet frame from one sender to one receiver

3.2.28 virtual link (VL)

logical unidirectional connection path between one node towards one or more nodes

[ARINC 664 part 7]

3.2.29 virtual link identifier (VL ID)

least significant 16 bits of the MAC Destination Address of a Critical Traffic Frame

NOTE Per definition of the standard [ARINC 664 part 7], the VL ID uniquely identifies a multicast group with a dedicated sender of the message and a set of receivers.

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms and symbols from ECSS-S-ST-00-01 and the following apply:

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Abbreviation	Meaning
API	Application Programming Interface
ARINC	Aeronautical Radio Incorporated
BAG	Bandwidth Allocation Gap
BE	Best effort
CD	Collision Detection
CM	Compression Master
CRC	Cyclic redundancy check
CSMA	Carrier Sense Multiple Access
CT	Critical traffic
DLL	Data Link Layer
ECSS	European Cooperation for Space Standardization
EMC	Electromagnetic compatibility
ES	End System
ESCC	European Space Components Coordination
FCS	Frame check sequence
FDIR	failure detection, isolation and recovery
FT	Fault Tolerant
Gbps	Giga bit per second
GMII	Gigabit media independent interface
GND	Ground
H/W	Hardware
IC	Integrity Checking
ICMP	Internet Control Message Protocol
ID	Identifier
IEEE	Institute of Electrical and Electronics Engineers
IFG	Inter frame gap
IHL	Internet Header Length
IP	Internet protocol
IP	Intellectual Property
ISO	international standard organisation
LAN	Local Area Network
LLC	Logic Link Control
LVDS	Low Voltage Differential Signalling
MAC	Media access control
Mbps	Mega bit per second
MIB	Management Information Base
MII	Media independent interface

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Abbreviation	Meaning
OSI	Open system interconnection
PCB	Printed circuit board
PCF	Protocol Control Frame
PCS	Physical Coding Sub-layer
PHY	Physical Layer
PLS	Physical Coding Sublayer
PMA	Physical Medium Attachment sub-layer
PMD	Physical Medium Dependent sub-layer
QoS	Quality of service
RC	Rate-constraint
RM	Redundancy Management
SAE	Society of Automotive Engineers
SC	Synchronization Client
SFD	Start Frame Delimiter
SM	Synchronization Master
SN	Sequence number
SNMP	Simple Network Management Protocol
SW	Switch
TFTP	Trivial File Transfer Protocol
TT	Time-triggered
UDP	User Datagram Protocol
VL	Virtual Link

3.4 Nomenclature

The following nomenclature applies throughout this document:

- The word “shall” is used in this Standard to express requirements. All the requirements are expressed with the word “shall”.
- The word “should” is used in this Standard to express recommendations. All the recommendations are expressed with the word “should”.

NOTE It is expected that, during tailoring, recommendations in this document are either converted into requirements or tailored out.

The words “may” and “need not” are used in this Standard to express positive and negative permissions, respectively. All the positive permissions are expressed with the word “may”. All the negative permissions are expressed with the words “need not”.

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The word “can” is used in this Standard to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

NOTE In ECSS “may” and “can” have completely different meanings: “may” is normative (permission), and “can” is descriptive.

The present and past tenses are used in this Standard to express statements of fact, and therefore they imply descriptive text.

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4 Overview

4.1 Reference Model

This Clause provides an overview of the Time-Triggered Ethernet Standard for the use of deterministic Ethernet in space applications. It covers the most important OSI model layers applicable for space applications and extensions providing useful features to the space community.

Time-Triggered Ethernet takes into consideration the [IEEE 802.3], as well as the [ARINC 664 part 7] and is specified in the Time-triggered Ethernet Standard [SAE AS6802].

[SAE AS6802] Time-Triggered Ethernet standard is a Layer 2 Quality-of-Service (QoS) enhancement that defines time-triggered services for Ethernet networks. Time-Triggered Ethernet is designed for the development of highly dependable systems for applications in multiple industries, including integrated systems in aerospace, ground vehicles and industrial process control. It provides the capability for deterministic, synchronous, and congestion-free communication among distributed applications, unaffected by any asynchronous Ethernet traffic load. [SAE AS6802] is fully compatible with lower (1-2) and higher OSI layers (3-7) and is transparent to applications designed to use asynchronous Ethernet (Figure 4-1)

Time-Triggered Ethernet is a full-duplex, bidirectional, point-to-point data link. It encodes data according to [IEEE 802.3] with 10/100/1000Mbps speeds. It further encompasses different media types as copper and fibre.



Figure 4-1: OSI Reference Model

4.2 Physical Layer

The physical level provides the actual interface between the network components including both the mechanical and electrical interface. This Clause covers:

- cable construction,
- connectors,

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- cable assemblies, and
- PCB and backplane tracking.

Ethernet was developed to meet the EMC specifications of high reliable applications cross industry. However, since there are lots of space applications where power consumption is a key requirement, in some cases, the use of LVDS as physical layer provides advantages over the typical Ethernet physical layer. Since Ethernet specifies also the interface to the Ethernet physical layer transceiver, the media independent interface (MII), this interface can be used with LVDS transceivers to provide a solution for short distances with already available physical layer building block. As illustrated in Figure 4-2, Ethernet specifies the following three different functional layers within the physical layer:

- PCS (Physical Coding Sub-layer),
- PMA (Physical Medium Attachment sub-layer), and
- PMD (Physical Medium Dependent sub-layer)

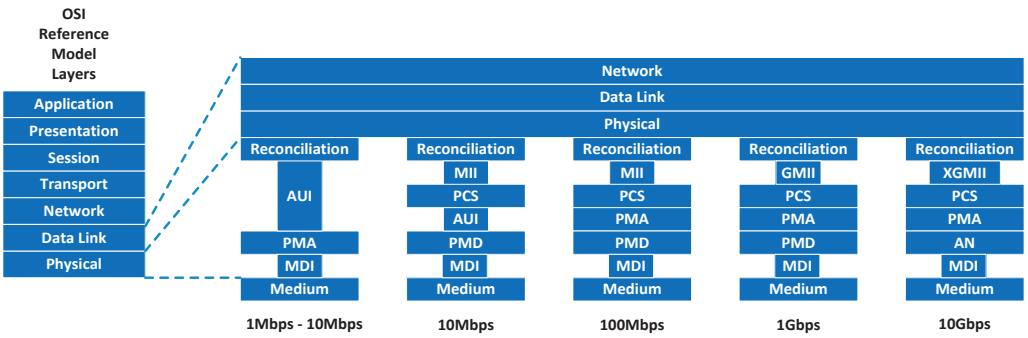


Figure 4-2: Physical Layer Model

4.3 Data Link Layer

4.3.1 Data Link Layer Overview

In a Local Area Network (LAN), the Data Link Layer consists of the Media Access Control (MAC) and the Logic Link Control (LLC) Sublayers as illustrated in Figure 4-3.

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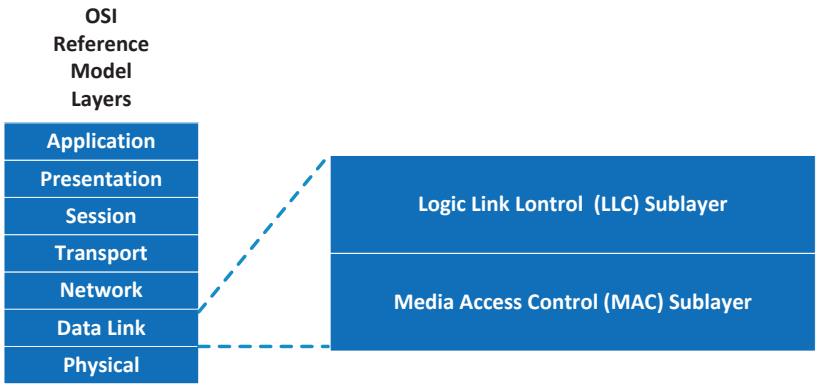


Figure 4-3: Data Link Layer

4.3.2 Data Link Layer Functionalities

The MAC sublayer defines a medium-independent facility, built on the medium-dependent physical facility provided by the Physical Layer, and under the access-layer-independent LAN LLC sublayer (or other MAC client). It is applicable to a general class of local area broadcast media suitable for use with the media access disciplines known as Time-triggered Ethernet and Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

The LLC sublayer and the MAC sublayer together are intended to have the same function as that described in the OSI model for the Data Link Layer alone. In a broadcast network, the notion of a data link between two network entities does not correspond directly to a distinct physical connection. Nevertheless, the partitioning of functions requires three main functions generally associated with a data link control procedure to be performed in the MAC sublayer. They are as follows:

- Data encapsulation (transmit and receive):
- Framing (frame boundary delimitation, frame synchronization)
- Addressing (handling of source and destination addresses)
- Virtual Link handling
- Error detection (detection of physical medium transmission errors)
- Media Access Management
- Medium allocation (collision avoidance)
- Contention resolution (collision handling)
- Network Synchronization
- Start-Up Service
- Restart Services
- Fault-Tolerant Clock Synchronization Service

The Media Access Management is not covered to a very large extend since this can be implemented as defined in the [IEEE 802.3]. For time-triggered traffic this is handled via the configurations of the devices in the network according to the global schedule created by the configuration tools. Also for rate-constraint traffic the flow-control of [IEEE 802.3] according to [ARINC 664 part 7] has to be disabled.

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4.3.3 Time-Triggered Ethernet

Time-Triggered Ethernet specifies time-triggered services that are added to the standards for Ethernet established in [IEEE 802.3]. Figure 4-4 shows a parallel view of the time-triggered services and the common Open Systems Interconnection OSI model layers. A communication controller that implements the time-triggered services can synchronize its local clock with the local clocks of other communication controllers and Switches in the system. A system designer can define an offline schedule of frame transmission with respect to the synchronized time, and the Time-Triggered Ethernet devices can then dispatch frames according to this schedule. Such a transfer of a frame according to a synchronized time is called a "time-triggered transfer". Offline scheduling tools can be used to guarantee that time-triggered transfers are conflict-free (i.e., no two time-triggered frames compete for transmission). Time-triggered communication is not priority-based and is driven only by time progression and frame schedule. This prevents network traffic congestion for time-triggered frames and enables communication with fixed latency in Ethernet networks, unaffected by any asynchronous Ethernet traffic load.

In addition to the time-triggered transfer service, a synchronized global time is used to specify temporal characteristics for intervals in which non-time-triggered communication can occur. This allows Time-Triggered Ethernet device implementations to support communication among applications with different real-time requirements over a single physical network. For example, in a particular Time-Triggered Ethernet system, there can be three different traffic classes (see Figure 4-4):

- Time-triggered TT [SAE AS6802],
- Rate-constrained RC [ARINC 664 part 7], and
- Best-effort BE [IEEE 802.3].

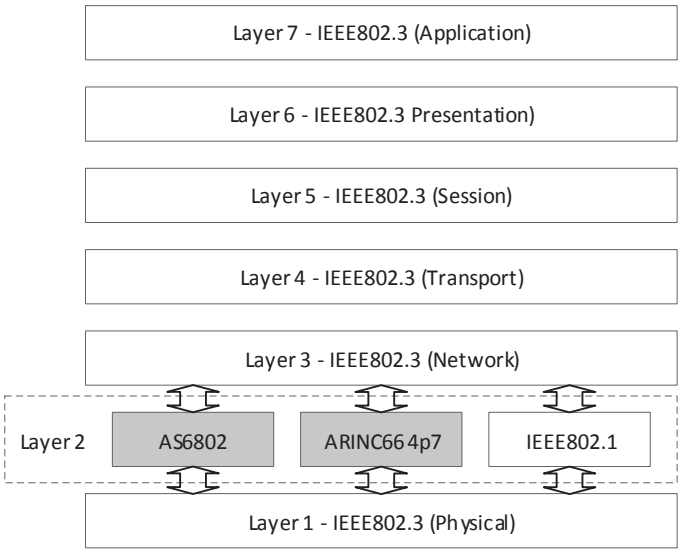


Figure 4-4: Time-Triggered Ethernet Services

Time-Triggered transfers (TT) best suit communications distributed in real-time systems. Tight latency, jitter, and determinism requirements can necessitate the use of TT transfers. All TT transfers are dispatched at predefined times. In cases

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where an end system decides not to use its assigned time slot (e.g., if there is no new data to send), the Switch recognizes the inactivity of the sender by not receiving the TT frame within the acceptance window and frees the bandwidth for the other traffic classes immediately afterwards.

Rate-constrained transfers (RC) define the maximum allowed bandwidth use for a dedicated message to ensure bounded latency in complex networks. Successive transfers of RC frames belonging to the same rate-constrained dataflow are guaranteed to be offset by a minimum duration as specified offline. This is in contrast to TT communication, which in addition to the minimum duration also specifies a maximum duration for this interval. The RC communications paradigm is specified in the standard [ARINC 664 part 7]. A system designer can decide to use RC transfers when determinism and real-time operating requirements are less strict than those that drive the use of TT communication. RC transfers guarantee sufficient bandwidth allocation for each transmission, with defined limits for delays and temporal deviations. In contrast to TT transfers, RC transfers are not dispatched with respect to a system-wide synchronized time base. Hence, different communication controllers can dispatch RC-transferred frames at the same point in time. Consequently, the RC transferred frames can queue up in the network Switches, leading to increased transmission jitter and requiring increased buffer space. Given the known transmission rate of the RC transfers and the network Switch controls, it is possible to avoid frame loss by calculating the transmission latency offline.

Best-effort transfers (BE) implement the classic Ethernet approach. There is no guarantee if and when these frames are transmitted, what delays can occur, or if BE-transferred frames arrive at the recipient location. BE transfers use the remaining bandwidth of the network and has a lower Quality of Service compared to TT and RC transfers.

TT services are concerned with configured frame transmission timing, not with the content of frames: as shown in Figure 4-4, frames from higher-layer protocols, such as IP or UDP, can easily become TT transfers without modification of the frames' content. TT services are concerned with configured frame transmission timing, not with the content of frames.

Other QoS protocols can be added to the Switch functionality and executed in a portion of bandwidth not used by TT-transferred frames. Time-Triggered Ethernet Switch implementations contain in a minimum configuration the support for synchronous TT.

As depicted in Figure 4-5, the available bandwidth is shared by different QoS services due to robust bandwidth partitioning.

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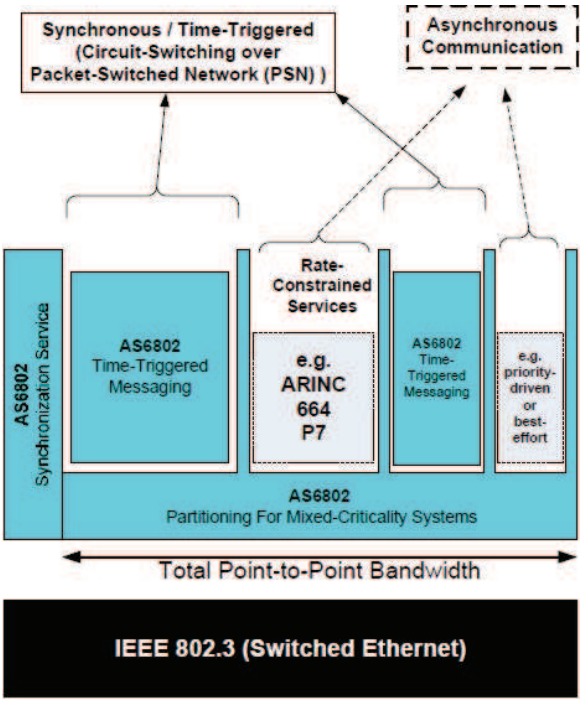


Figure 4-5: Traffic Partitioning

4.4 Network Level

4.4.1 Network Level Overview

A Time-Triggered Ethernet network is a Switch Ethernet based network - star topology - composed of end systems, Switches and links. End systems are the sources and destinations of the Ethernet packets and the Switch routes the packets according to a pre-established TTE configuration.

As an example, an on-board avionics computer composed of a micro-processor with a TTE communication controller interface is an End System, the physical connections between the End Systems are the links and the Switches provide the means for passing frames between the End Systems. The links are connected to the communication ports of the End Systems and Switches.

Figure 4-6 illustrates a basic switched communication network composed of two End Systems and one Switch. The End Systems have one full duplex communication port which is connected via a link to a communication port of the Switch. Depending on the fault tolerance needed, an End System supports a given number of ports (up to three for dual fault-tolerance). The Switch in the example represented below has two communication ports.

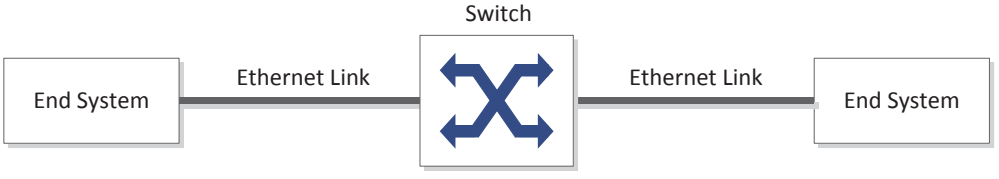


Figure 4-6: Network Communication Channel

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An example network comprising several End Systems and Switches is illustrated in Figure 4-6. Switches are connecting multiple End Systems with each other and provide a means of switching packets from one End System to one of many other possible End Systems. Switches can also be cascaded to a larger network allowing the connection of much more End Systems.

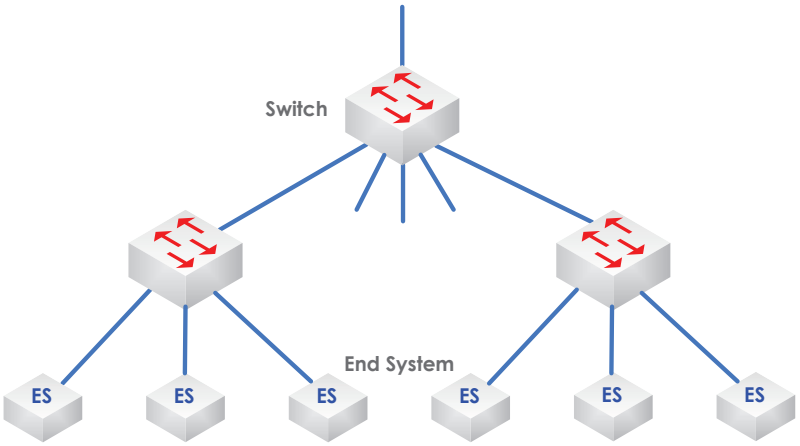


Figure 4-7: A TTE example network

Packets can be transferred from one End System to another through one or more Switches. The frames exchanged by the end systems and forwarded by the Switches are fully compliant to the [IEEE 802.3] frame layout.

An example network comprising several End Systems and Switches is illustrated in Figure 4-7. This figure is for illustrative purposes and does not show a practical network. Packets can be transferred from one End System to another through one or more Switches.

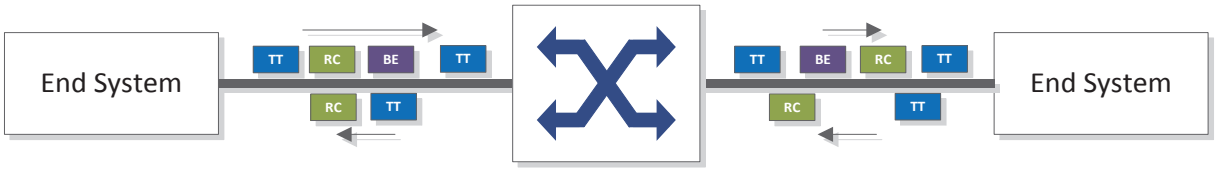


Figure 4-8: Full Duplex Links

In switched Time-Triggered Ethernet the links are full duplex which means that sending and receiving of all traffic classes (TT, RC and BE) is possible at the same time as illustrated in Figure 4-8.

The frames exchanged by the end systems and forwarded by the Switches are fully compliant to the [IEEE 802.3] frame layout as defined in Figure 4-4.

4.4.2 Message Processing at the Switch

TTEthernet uses store and forward Switching which means that the messages are fully received by the Switch and are then be checked for consistency, timing, frame layout, CRC, … until they are placed into the dedicated output queue.

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A message conflict (whatever nature) can cause a delay of a message transmission until the transmission resource (port/link) becomes free. The pending messages are buffered, and their transmission is deferred. A message delay has different impacts on different traffic classes:

- Best-effort (BE): does not have any timing guarantees
- Rate-Constrained: Introduce a jitter
- Time-Triggered: delays a frame, frame can be received outside the receive window

Possible scenarios are:

- Simultaneous TT-TT message conflict
  - Correct configuration schedules ensure that such message conflicts do not exist.
- Simultaneous RC-RC message conflict
  - Priority mechanisms resolve the conflict.
  - Among the same priority: internal priority level based on source port number.
- Simultaneous TT-RC message conflict
  - Priority mechanisms resolve the conflict.
- Simultaneous TT-BE or RC-BE message conflict
  - TT or RC over best effort

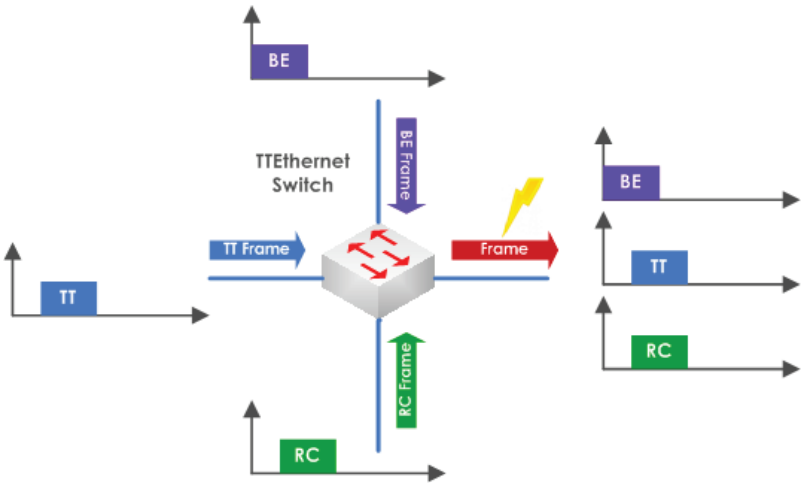


Figure 4-9: Message Processing at the Switch

In case an Ethernet frame is processed on the dedicated Switch port and a time-triggered send windows is dispatched as illustrated in Figure 4-9 there has to be a defined strategy for processing these two frames using the shared physical media.

The three different possible mechanisms are described below:

- Preemption
- Shuffling
- Media Reservation

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