BS EN 61375-2-5:2015

BSI Standards Publication

Electronic railway equipment — Train communication network (TCN)

Part 2-5: Ethernet train backbone

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National foreword

This British Standard is the UK implementation of EN 61375-2-5:2015. It is identical to IEC 61375-2-5:2014.

The UK participation in its preparation was entrusted by Technical Committee GEL/9, Railway Electrotechnical Applications, to Panel GEL/9/-/4, Railway applications - Train communication network and multimedia systems.

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This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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This European Standard was approved by CENELEC on 2014-09-29. 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 Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 9/1933/FDIS, future edition 1 of IEC 61375-2-5, prepared by IEC/TC 9 "Electrical equipment and systems for railways" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61375-2-5:2015.

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The text of the International Standard IEC 61375-2-5:2014 was approved by CENELEC as a European Standard without any modification.

IEC 61375-2-1:2012	NOTE	Harmonized as EN 61375-2-1:2012.
IEC 61784-2	NOTE	Harmonized as EN 61784-2.
IEC 61918	NOTE	Harmonized as EN 61918.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

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

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

Publication	Year	Title	EN/HD	Year
IEC 61076-2-101	2012	Connectors for electronic equipment - Product requirements -- Part 2-101: Circular connectors - Detail specification for M12 connectors with screw-locking	EN 61076-2-101	2012
IEC 61156	series	Multicore and symmetrical pair/quad cables for digital communications	-	series
IEC 61156-1	2007	Multicore and symmetrical pair/quad cables for digital communications - Part 1: Generic specification	-	-
IEC 61156-5	-	Multicore and symmetrical pair/quad cables for digital communications - Part 5: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz - Horizontal floor wiring - Sectional specification	-	-
IEC 61375-1	2012	Electronic railway equipment - Train communication network (TCN) -- Part 1: General architecture	EN 61375-1	2012
IEC 61375-2-3	-	Electronic railway equipment - Train Communication Network (TCN) - Part 2-3: TCN communication profile	FprEN 61375-2-3	-
IEC 61375-3-4	-	Electronic railway equipment - Train Bus - Part 3-4: ECN - Ethernet Consist Network	EN 61375-3-4	-
IEC 62236-3-2	-	Railway applications - Electromagnetic compatibility -- Part 3-2: Rolling stock - Apparatus	-	-
ISO/IEC 7498	series	Information processing systems - Open systems interconnection - Basic reference model	-	series
ISO/IEC 8824	series	Information technology - Abstract Syntax Notation One (ASN.1)	-	series
ISO/IEC 9646	series	Information technology - Open Systems Interconnection	EN ISO/IEC 9646	series
ISO/IEC 11801	2002	Information technology - Generic cabling for customer premises	-	-
IEEE 802.1AB	-	IEEE Standard for Local and Metropolitan Area Networks - Station and Media Access Control Connectivity Discovery	-	-
IEEE 802.1AX	2008	IEEE Standard for Local and metropolitan area networks - Link Aggregation	-	-

IEEE 802.1D	2012	IEEE Standard for local and metropolitan area networks - Media Access Control (MAC) Bridges	-	-
IEEE 802.1Q	-	IEEE Standard for Local and metropolitan area networks - Media Access Control (MAC) Bridges and Virtual Bridges	-	-
IEEE 802.2	-	IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 2: Logical Link Control	-	-
IEEE 802.3	2012	IEEE Standard for Ethernet	-	-

Annex ZZ
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2008/57/EC

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers all relevant essential requirements as given in Annex III of the EC Directive 2008/57/EC (also named as New Approach Directive 2008/57/EC Rail Systems: Interoperability).

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZZ.1 relating to the 'rolling stock - locomotives and passenger rolling stock' subsystem of the rail system in the European Union, confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZZ.1 - Correspondence between this European Standard, the RST LOC&PAS TSI (published in the Official Journal L 356 on 12 December 2014, p. 228) and Directive 2008/57/EC

Clauses of this European Standard	Chapter / § / points / of RST LOC&PAS TSI	Essential Requirements (ER) of Directive 2008/57/EC	Comments
The whole standard is applicable	4.2.4.9 Brake state and fault indication 4.2.5.2 Audible communication system 4.2.5.3 Passenger alarm 4.2.5.4 Communication devices for passengers 4.2.5.5 Exterior doors 4.2.12.2 General documentation: - description of computerised onboard systems	2. Requirements specific to each sub-subsystem 2.4. Rolling Stock 2.4.1. Safety 2.4.2. Reliability and availability 2.4.3. Technical compatibility	The TSI does not impose any technical solution regarding physical interfaces between units. The standard offers a general multi-purpose solution for the inter-vehicle digital communication network and it is relevant to vehicle interoperability.

WARNING: Other requirements and other EU Directives may be applicable to the products falling within the scope of this standard.

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INTRODUCTION

IEC 61375-2-5 defines the Ethernet Train Backbone so as to achieve interoperability between Consists of different types when coupled in the same train composition.

The standard follows the ISO-OSI model and specifies the whole protocols stack from the physical layer up to the application layer.

A Protocol Implementation Conformance Statement (PICS) pro-forma allows suppliers to state their conformity to this standard. The PICS pro-forma specification and the related conformity test are not in the scope of this standard.

ELECTRONIC RAILWAY EQUIPMENT – TRAIN COMMUNICATION NETWORK (TCN) –

Part 2-5: Ethernet train backbone

1 Scope

This part of IEC 61375 defines Ethernet Train Backbone (ETB) requirements to fulfil open train data communication system based on Ethernet technology.

Respect of this standard ensures interoperability between local Consist subnets whatever Consist network technology (see IEC 61375-1 for more details).

All Consist network definitions should take into account this standard to preserve interoperability.

This standard may be additionally applicable to closed trains and multiple-unit trains when so agreed between purchaser and supplier.

2 Normative references

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

IEC 61076-2-101:2012, *Connectors for electronic equipment – Product requirements – Part 2-101: Circular connectors – Detail specification for M12 connectors with screw-locking*

IEC 61156 (all parts), *Multicore and symmetrical pair/quad cables for digital communications*

IEC 61156-1:2007, *Multicore and symmetrical pair/quad cables for digital communications – Part 1: Generic specification*

IEC 61156-5, *Multicore and symmetrical pair/quad cables for digital communications – Part 5: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Horizontal floor wiring – Sectional specification*

IEC 61375-1:2012, *Electronic railway equipment – Train communication network (TCN) – Part 1: General architecture*

IEC 61375-2-3, *Electronic railway equipment – Train communication network (TCN) – Part 2-3: TCN communication profile* (to be published)

IEC 61375-3-4, *Electronic railway equipment – Train communication network (TCN) – Part 3-4: Ethernet Consist Network (ECN)*

IEC 62236-3-2, *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus*

ISO/IEC 7498 (all parts), *Information technology – Open System Interconnection – Basic Reference Model*

ISO/IEC 8824 (all parts), *Information technology – Abstract Syntax Notation One (ASN.1)*

ISO/IEC 9646 (all parts), *Information technology – Open Systems Interconnection – Conformance testing methodology and framework*

ISO/IEC 11801:2002, *Information technology – Generic cabling for customer premises*

IEEE 802.1AB, *IEEE Standard for Local and metropolitan area networks – Station and Media Access Control Connectivity Discovery*

IEEE 802.1AX:2008, *IEEE Standard for Local and metropolitan area networks – Link Aggregation*

IEEE 802.1D:2012, *IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Bridges*

IEEE 802.1Q, *IEEE Standard for Local and metropolitan area networks – Virtual Bridged Local Area Networks*

IEEE 802.2, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 2: Logical Link Control*

IEEE 802.3:2012, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

3 Terms, definitions, symbols, abbreviations and conventions

3.1 Terms and definitions

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

3.1.1
application layer
upper layer in the OSI model, interfacing directly to the Application

3.1.2
application process
element within a real open system which performs the information processing for a particular application

3.1.3
bridge
device which stores and forwards frames from one bus to another on the base of their Link Layer addresses

3.1.4
broadcast
nearly simultaneous transmission of the same information to several destinations

Note 1 to entry: Broadcast in the TCN is not considered reliable, i.e. some destinations may receive the information and others not.

3.1.5
bus
communication medium which broadcasts the same information to all attached participants at nearly the same time, allowing all devices to obtain the same sight of its state, at least for the purpose of arbitration

3.1.6
closed train
train composed of one or a set of Consists, where the configuration does not change during normal operation, for instance metro, sub-urban train, or high speed train units

3.1.7
communication devices
devices connected to Consist Network or Train Backbone with the ability to source and sink data

3.1.8
composition
number and characteristics of the vehicles forming a train

3.1.9
configuration
definition of the topology of a network, the devices connected to it, their capabilities and the traffic they produce; by extension, the operation of loading the devices with the configuration information before going to regular operation

3.1.10
consist
train set
rake of coaches
single vehicle or a group of vehicles which are not separated during normal operation. A Consist contains no, one or several Consist networks.

3.1.11
Consist Network
CN
communication network interconnecting communication devices in one Consist

3.1.12
End Device
ED
unit connected to one Consist Network or to one set of Consist Networks prepared for redundancy reasons

3.1.13
end node
node which terminates the Train Backbone

3.1.14
function
Application Process which exchanges messages with another Application Process

3.1.15
gateway
connection between different communication technologies

3.1.16
group address
address of a multicast group to which a device belongs

3.1.17
host
any addressable unit connected to the network: End Devices, Network Devices, etc.

3.1.18
inauguration
operation executed in case of composition change, which gives all Nodes of the Train Backbone their Train Backbone address, their orientation and information about all named Nodes on the same backbone

3.1.19
integrity
property of a system to recognize and to reject wrong data in case of malfunction of its parts

3.1.20
intermediate node
node which establishes continuity between two bus sections connected to it, but does not terminate them

3.1.21
linear topology
topology where the nodes are connected in series, with two nodes each connected to only one other node and all others each connected to two other nodes (that is, connected in the shape of a line)

3.1.22
Local Area Network
part of a network characterized by a common medium access and address space

3.1.23
Medium Access Control
sublayer of the Link Layer, which controls the access to the medium (arbitration, mastership transfer, polling)

3.1.24
medium
physical carrier of the signal: electrical wires, optical fibers, etc.

3.1.25
message
data item transmitted in one or several packets

3.1.26
Mobile Train Unit
part of a train which shall be uniquely addressable from ground. A mobile train unit provides one active mobile communication gateway for train to ground communication.

3.1.27
multicast
transmission of the same message to a group of receivers, identified by their Group Address

Note 1 to entry: The word "multicast" is used even if the group includes all receivers.

3.1.28
network
set of possibly different communication systems which interchange information in a commonly agreed way

3.1.29
network address
address which identifies a communication device on network layer

3.1.30
network device
ND
components used to set up Consist Networks and Train Networks

Note 1 to entry: These may be passive components such as cables or connectors, active unmanaged components such as repeaters, media converters or (unmanaged) switches, or active managed components such as gateways, routers and (managed) switches.

3.1.31
network layer
layer in the OSI model responsible for routing between different busses

3.1.32
network management
operations necessary to remotely configure, monitor, diagnose and maintain the network

3.1.33
node
device on the Train Backbone, which may act as a gateway between Train Backbone and Consist Network

3.1.34
open train
train composed of a set of Consists, where the configuration may change during operation, for instance international trains

3.1.35
operator
enterprise or organization which operates trains

3.1.36
packet
unit of a message (information, acknowledgement or control) transmitted by protocols on network or transport layer

3.1.37
receiver
electronic device which may receive signals from the physical medium

3.1.38
repeater
connection at the Physical Layer between bus segments, providing an extension of the bus beyond the limits permitted by passive means

Note 1 to entry: The connected segments operate at the same speed and with the same protocol. The delay introduced by a repeater is in the order of one bit duration.

3.1.39
router
connection between two busses at the Network Layer, which forwards datagrams from one bus to another on the base of their Network Address

3.1.40
service
capabilities and features of a sub-system (e.g. a communication layer) provided to a user

3.1.41
switch
MAC bridge as defined in IEEE 802.1D

3.1.42
topology
possible cable interconnection and number of devices a given network supports

3.1.43
topology counter
counter in a node which at each Inauguration memorises CRC of Train Network Directory

3.1.44
train communication network
data communication network for connecting programmable electronic equipment on-board rail vehicles

3.1.45
train backbone
bus connecting the vehicles of a train and which conforms to the TCN protocols

3.1.46
train backbone node
node device on the Train Backbone which receives a train backbone node number during Inauguration. A train backbone node can be used to connect an End Device or a Consist Network to the Train Backbone.

3.1.47
train backbone node number
node address
node number
each active train backbone node is assigned a number during Inauguration, which indicates the position of the train backbone node on the Train Backbone

3.1.48
transport layer
layer of the OSI model responsible for end-to-end flow control and error recovery

3.2 Symbols and abbreviations

CAN	Controller Area Network
CCTV	Closed Circuit Television
CIDR	Classless Inter Domain Routing
CN	Consist Network
CRC	Cyclic Redundancy Check
CSTINFO	ConSisT INFOrmation
CstUUID	Consist Universally Unique IDentifier

DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
ECN	Ethernet Consist Network
ED	End Device
EMC	Electro Magnetic Compatibility
ETB	Ethernet Train Backbone
ETBN	Ethernet Train Backbone Node
FLR	Frame Loss Rate
FQDN	Fully Qualified Domain Name
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
LACP	Link Aggregation Control Protocol
LAG	Link Aggregation Group
LLDP	Link Layer Discovery Protocol
LLDPDU	LLDP Data Unit
MAC	Medium Access Control
MCG	Mobile Communication Gateway
MDI	Media Dependent Interface
MTU	Maximum Transmission Unit
MVB	Multifunction Vehicle Bus
NAT	Network Address Translation
ND	Network Device
NTP	Network Time Protocol
OSI	Open System Interconnection
PCS	Physical Coding Sublayer
PD	Powered Device (about PoE)
PD/MD	Process Data/Message Data
PICS	Protocol Implementation Conformance Statement
PMA	Physical Medium Attachment
PMD	Physical Medium Dependent
PoE	Power Over Ethernet
PSE	Power Source Equipment (about PoE)
RFC	Request For Comments
TBN	Train Backbone Node
TCMS	Train Control and Monitoring System
TCN	Train Communication Network
TCP	Transport Control Protocol
TLV	Type/Length/Value
TNDir	Train Network Directory
TTDP	Train Topology Discovery Protocol
UDP	User Data protocol
UML	Unified Modeling Language

VLAN	Virtual Local Area Network
WTB	Wire Train Bus
XML	eXtensible Markup Language

3.3 Conventions

3.3.1 Base of numeric values

This standard uses a decimal representation for all numeric values unless otherwise noted.

Analog and fractional values include a comma.

EXAMPLE The voltage is 20,0 V.

Binary and hexadecimal values are represented using the ASN.1 (ISO/IEC 8824) convention.

EXAMPLE Decimal 20 coded on 8 bits = ‘0001 0100’B = ‘14’H.

3.3.2 Naming conventions

Keywords are written with a capital letter at the beginning.

If the keyword name is composed, the different parts of the name are united with a space, and all parts begin with a capital letter.

EXAMPLES “Train Backbone”, “Consist”, “Consist Network”.

Parameters are written with a capital letter at the beginning.

If the parameter name is composed, the different parts of the name are united without a space, and all parts begin with a capital letter.

EXAMPLE “NumberOfConsists“.

3.3.3 State diagram conventions

State diagrams are defined following the notation of UML state machines.

3.3.4 Annotation of data structures

Data structures are defined following ISO ASN.1 syntax. A superset of ASN.1 defined in IEC 61375-2-1:2012, 6.4 ”Presentation and encoding of transmitted and stored data” is also used.

All data within a data structure are organized in big-endian format (most significant octet of a data item first).

4 ETB physical layer

4.1 Train regions

ETB use physical lines along the train to connect the active network devices together (ETBN, Repeater, etc.). These lines are also called physical segments, and shall use passive components such as cables and connectors, dedicated to Ethernet.

Along the train, three regions shall be distinguished for the ETB network (see Figure 1 below):

– **Intra Car:** Passive components (cabling) and active network devices inside a car (or locomotive, etc.).

– **Inter Car**: Passive components (cabling) at the interface between 2 cars. This category refers also to optional active network devices outside the car (such as under body, etc.).

– **Inter Consist**: Passive components (cabling) at the interface between 2 Consists using a manual coupler, or auto coupler. This category refers also to optional active network devices outside the car.

These regions are characterized by different train contexts and environments (mechanical, thermal, EMC, etc.). As a consequence, cabling (cables and connectors) are different on these 3 regions.

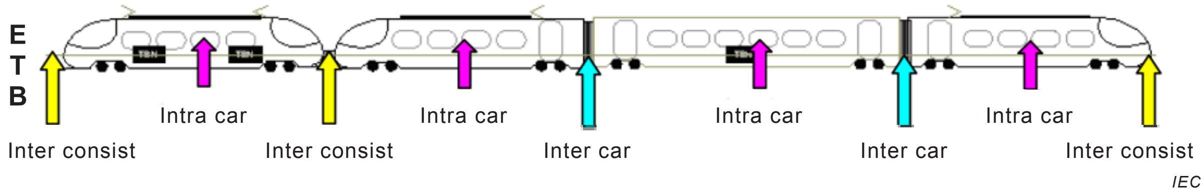


Figure 1 – ETB train regions

4.2 Physical characteristics

4.2.1 General

The following tables summarize network physical layer requirements for passive components (cables and connectors) and active network devices (ETBN, Repeater,etc.) depending on the 3 regions defined.

4.2.2 Intra car physical layer

Table 1 below defines the physical layer requirements.

(M: Mandatory, O: Optional, C: Conditional, X: Prohibited)

Table 1 – ETB Intra car physical layer interface *(1 of 2)*

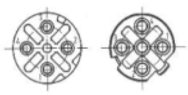
<table>
<tr><th colspan="4">ETB Intra car physical layer interface</th></tr>
<tr><th>OSI Layers</th><th>Requirements</th><th>Type</th><th>Description</th></tr>
<tr><td rowspan="7">Application
Presentation
Session
Transport
Network
Data
Physical</td><td>100 BASE TX Physical Layer Coding, Medium attachment and Medium Dependent Access (PCS, PMA, PMD) for Copper cables</td><td>M</td><td>Conformance to IEEE 802.3:2012, Clauses 24 and 25</td></tr>
<tr><td>Full Duplex Mode</td><td>M</td><td>Conformance to IEEE 802.3:2012, Clause 25
Bidirectional data flow at the same time on TX and RX double pair Ethernet</td></tr>
<tr><td>Physical Layer auto-Negotiation</td><td>X</td><td>Conformance to IEEE 802.3:2012, Clause 28
Prohibited on the ETB backbone.</td></tr>
<tr><td>Physical Layer crossover</td><td>M</td><td>Conformance to IEEE 802.3:2012,25.4.8
Just one crossover shall be made on a line between 2 ports (ETBN,etc.)</td></tr>
<tr><td>Physical layer auto-polarity/auto-sensing</td><td>X</td><td>Prohibited due to fixed cabling, and non-normalized solution</td></tr>
<tr><td>By-pass relay on ETBN ports</td><td>M</td><td>If ETB switch is out of order (e.g. powerless) train backbone ports are bypassed</td></tr>
<tr><td>Power over Ethernet (PoE)</td><td>O</td><td>Conformance to IEEE 802.3:2012, Clause 33
Called also: Data terminal equipment (DTE) Power via Medium Dependent Interface (MDI)
PSE or PD mode supported
See 4.3 for more details</td></tr>
<tr><td rowspan="3"></td><td>Connector for active Network Devices M12 D coded</td><td>M</td><td>Crimped contacts recommended
Female connector on active network device, male connector on train cable
Conformance to IEC 61076-2-101, which defines the pin out:
<table>
<tr><th>Signal</th><th>Function</th><th>Cable wire colour</th><th>M12 D-coding contact number</th></tr>
<tr><td>TD+</td><td>Transmission Data +</td><td>Yellow</td><td>1</td></tr>
<tr><td>TD-</td><td>Transmission Data -</td><td>Orange</td><td>3</td></tr>
<tr><td>RD+</td><td>Receiver Data +</td><td>White</td><td>2</td></tr>
<tr><td>RD-</td><td>Receiver Data -</td><td>Blue</td><td>4</td></tr>
</table>

Female and male connector</td></tr>
<tr><td>Connector for interior cabling (between walls, cabinets, container, etc.)</td><td>O</td><td>Ethernet circular cell arranged in a quartet distribution.
Pin out distribution identical to M12:
TD+: Contact 1,TD-: Contact 3
RD+: Contact 2, RD-: Contact 4</td></tr>
<tr><td>Cables CAT5e</td><td>M</td><td>Conformance to ISO/IEC 11801 and IEC 61156-5
Two pairs shielded or unshielded: See screening practices ISO/IEC 11801:2002,Clause 11.
The conductor shall be an annealed copper stranded conductor, in accordance with 5.2.1 of IEC 61156-1:2007 and should have a nominal diameter between 0,5 mm and 0,65 mm. A conductor diameter of up to 0,8 mm may be used if compatible to connecting hardware</td></tr>
</table>

Table 1 *(2 of 2)*

ETB Intra car physical layer interface			
OSI Layers	**Requirements**	**Type**	**Description**
	Segment performance	M	Segment (D-class) include cables, connectors, and port devices – EMC IEC 62236-3-2 for immunity and emission referred to rolling stock apparatus; Criteria acceptance type A: During test, Frame Loss Rate (FLR) shall be below a trigger value. To be defined depending on application. – Ethernet Certification compliant to ISO/IEC 11801 (conformance test category) • Cables shall be compliant with Clause 9 of ISO/IEC 11801:2002 • Connectors shall be compliant with Clause 10 of ISO/IEC 11801:2002 • ;The Telecommunication outlet (TO) is the M12 instead of the RJ45 • Channel shall be compliant with Clause 6 of ISO/IEC 11801:2002. Channel comprises sections of cable, connecting hardware, work area cords, equipment cords and patch cords.

It has to be noted that the number of connectors on an Ethernet physical segment and the length of the cable are not indicated in the table. Instead, a minimum requirement of electric performance and compliance to ISO/IEC 11801 is defined. It means that the electric parameters of a cabling depend not only on the number of connectors and the cable length, but also on some more complex parameters like shield, type of connectors, quality of cabling, installation,etc. As a consequence, it is proposed a global concept of verification in being compliant to the electric Ethernet parameters ISO/IEC 11801.

Inside a car, all shields of cables and connectors shall be connected to the mechanical earth of the car. To prevent EMC influences, a cable shield shall be connected on a 360° circular basis in the connector.

4.2.3 Inter car physical layer

4.2.3.1 General

Table 2 below defines the physical layer requirements.

(M: Mandatory, O: Optional, C: Conditional, X: Prohibited)

Table 2 – ETB Inter car physical layer interface *(1 of 2)*

ETB Inter car physical layer interface			
OSI Layers	**Requirements**	**Type**	**Description**
Application Presentation Session Transport Network Data **Physical**	100 BASE TX Physical Layer Coding, Medium attachment and Medium Dependent Access (PCS, PMA, PMD) for Copper cables	M	Conformance to IEEE 802.3:2012, Clauses 24 and 25
	Full Duplex Mode	M	Conformance to IEEE 802.3:2012, Clause 25 Bidirectional data flow at the same time on TX and RX double pair Ethernet
	Physical Layer auto-Negotiation	X	Conformance to IEEE 802.3:2012, Clause 28. Prohibited on the ETB backbone
	Physical Layer crossover	M	Conformance to IEEE 802.3:2012, 25.4.8 Just one crossover shall be made on a line between 2 ports (ETBN,etc.)
	Physical layer auto-polarity/auto-sensing	X	Prohibited due to fixed cabling, and non-normalized solution
	Power over Ethernet (PoE)	O	IEEE 802.3:2012, Clause 33 Called also: Data terminal equipment (DTE) Power via Medium Dependent Interface (MDI) PSE or PD mode supported. See 4.3 for more details.
	Connector for inter car	O	Specific connector different from M12 connector. Ethernet circular cell arranged in a quartet. Pin out distribution identical to M12: TD+: Contact 1,TD-: Contact 3 RD+: Contact 2, RD-: Contact 4
	Cables CAT5e	M	ISO/IEC 11801, IEC 61156 Shielded or unshielded: See screening practices ISO/IEC 11801:2002, Clause 11. The conductor shall be an annealed copper stranded conductor, in accordance with 5.2.1 of IEC 61156-1:2007 and should have a nominal diameter between 0,5 mm and 0,65 mm. A conductor diameter of up to 0,8 mm may be used if compatible to connecting hardware.

Table 2 *(2 of 2)*

ETB Inter car physical layer interface			
OSI Layers	**Requirements**	**Type**	**Description**
	Segment performance	M	Segment (D-class) includes cables, connectors, and port devices – EMC IEC 62236-3-2 for immunity and emission referred to rolling stock apparatus; Criteria acceptance type A: During test, Frame Loss Rate (FLR) shall be below a trigger value. To be defined depending on application. – Ethernet Certification compliant to ISO/IEC 11801 (conformance test category) • Cables shall be compliant with Clause 9 of ISO/IEC 11801:2002 • Connectors shall be compliant with Clause 10 of ISO/IEC 11801:2002; The Telecommunication outlet (TO) is the inter-car connector instead of the RJ45 • Channel shall be compliant with Clause 6 of ISO/IEC 11801:2002 Channel comprises sections of cable, connecting hardware, work area cords, equipment cords and patch cords.

It has to be noted that the number of connectors on an Ethernet physical segment and the length of the cable are not indicated in the table. Instead, a minimum requirement of electric performance and compliance to ISO/IEC 11801 is defined. It means that the electric parameters of a cabling depend not only on the number of connectors and the cable length, but also on some more complex parameters like shield, type of connectors, quality of cabling, installation,etc. As a consequence, it is proposed a global concept of verification in being compliant to the electric Ethernet parameters ISO/IEC 11801.

Two use cases have to be considered:

– The two adjacent cars are at the same potential.
– The two adjacent cars are at a different potential.

4.2.3.2 Inter Car at same potential

For information only:

A braid connects two adjacent cars which therefore are at the same potential. The Ethernet shield could have the continuity from car N to car N+1; in this case, no interruption of shielding is necessary (see Figure 2).

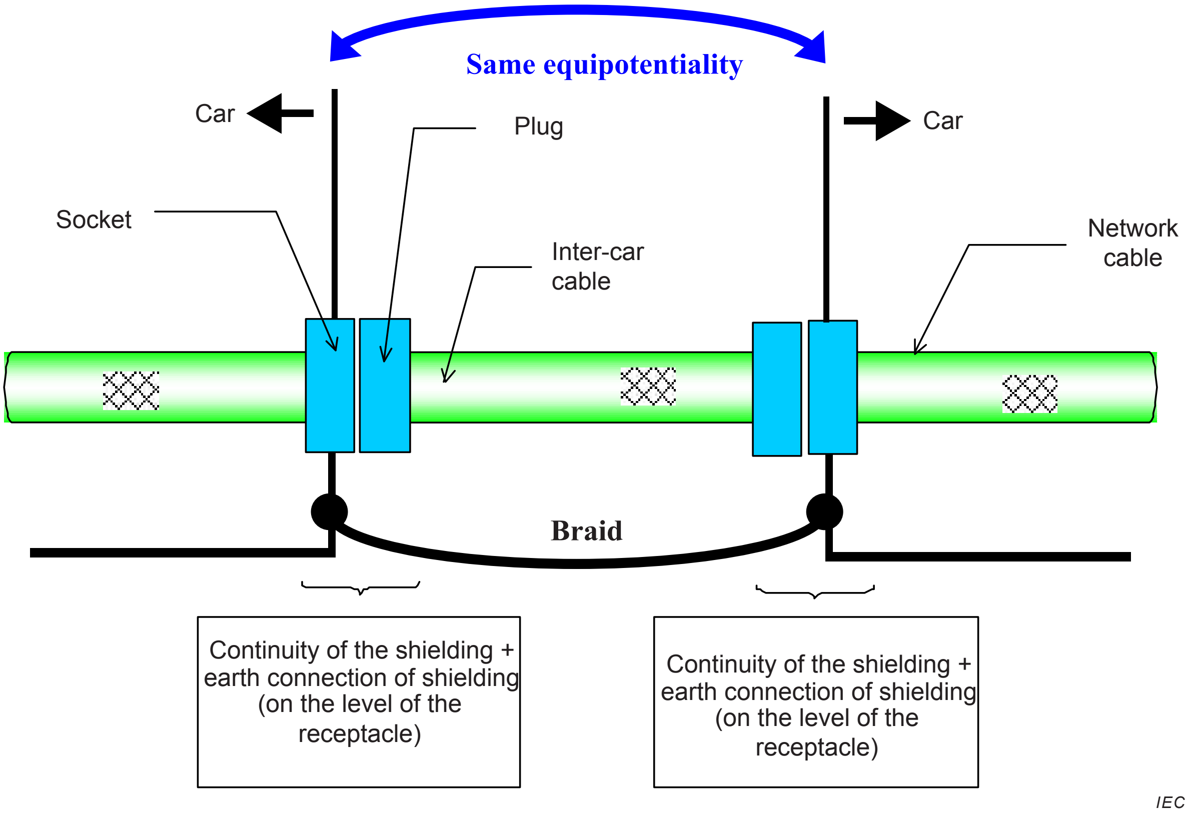


Figure 2 – ETB Inter car at same potential

4.2.3.3 Inter Car not at the same potential

For information only:

In some cases, the inter car cannot be at the same potential: Refurbishment, etc. Therefore, the Ethernet cable shield could be interrupted to avoid ground current flowing between cars (see Figure 3).

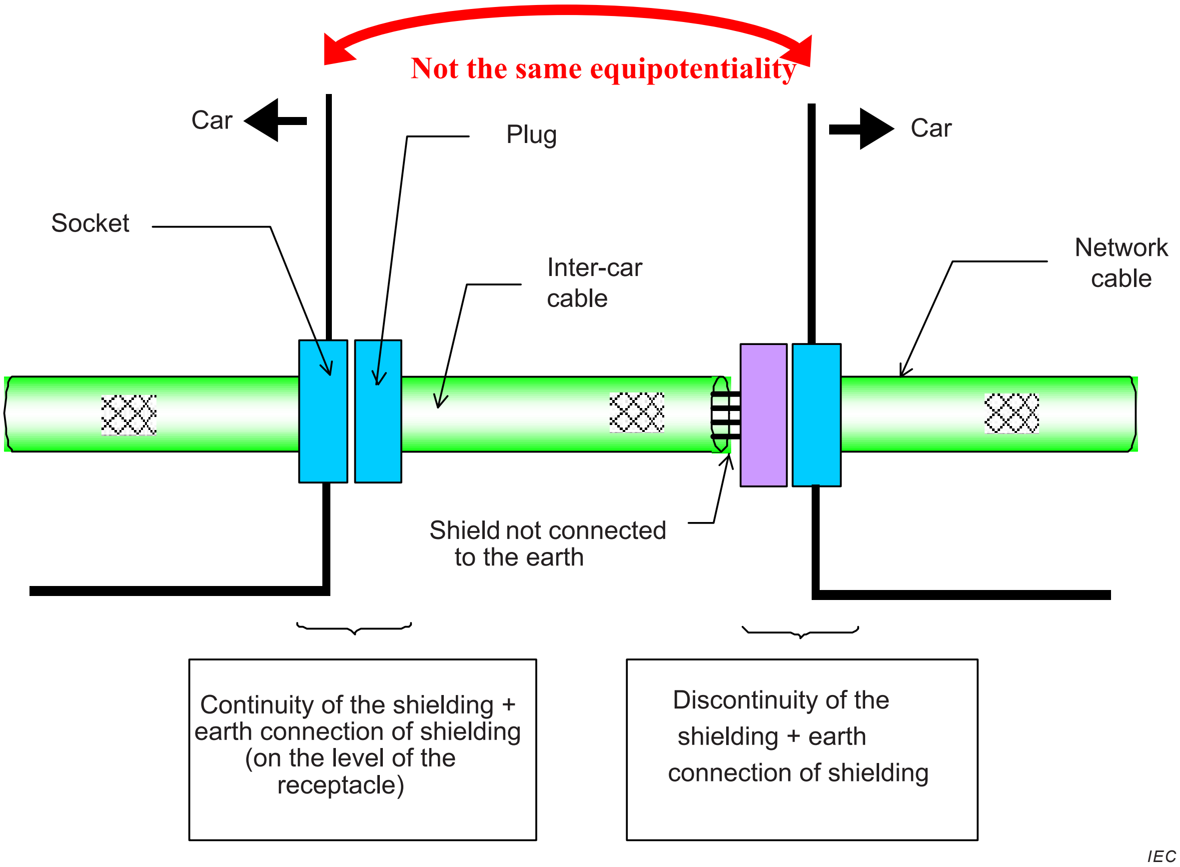


Figure 3 – ETB Inter car not at the same potential

NOTE The implementation of the shielding solution is not in the scope of this standard.

4.2.4 Inter Consist physical layer

Table 3 below defines the physical layer requirements.

(M: Mandatory, O: Optional, C: Conditional, X: Prohibited)

Table 3 – ETB Inter consist physical layer interface *(1 of 2)*

ETB Inter consist physical layer interface			
OSI Layers	**Requirements**	**Type**	**Description**
Application Presentation Session Transport Network Data **Physical**	100 BASE TX Physical Layer Coding, Medium attachment and Medium Dependent Access (PCS, PMA, PMD) for Copper cables	M	Conformance to IEEE 802.3, Clauses 24 and 25
	Full Duplex Mode	M	Conformance to IEEE 802.3, Clause 25 Bidirectional data flow at the same time on TX and RX double pair Ethernet
	Physical Layer auto-Negotiation	X	Conformance to IEEE 802.3, Clause 28. Prohibited on the ETB backbone
	Physical Layer crossover	M	Conformance to IEEE 802.3, 25.4.8 Just one crossover shall be made on a line between 2 ports (ETBN, etc.) Straight (MDI) on the male connector auto coupler side, crossover (MDI-X) on the female connector auto coupler side
	Physical layer auto-polarity/auto-sensing	X	Prohibited due to fixed cabling, and non-normalized solution
	Power over Ethernet (PoE)	O	IEEE 802.3, Clause 33 Called also: Data terminal equipment (DTE) Power via Medium Dependent Interface (MDI) PSE or PD mode supported. See 4.3 for more details.
	Connector for inter Consist	O	Specific connector different from M12 connector. Ethernet circular cell arranged in a quartet. Pin out distribution identical to M12: TD+: Contact 1,TD-: Contact 3 RD+: Contact 2, RD-: Contact 4
	Cables CAT5e	M	ISO/IEC 11801, IEC 61156 Shielded or unshielded: See screening practices ISO/IEC 11801, Clause 11. The conductor shall be an annealed copper stranded conductor, in accordance with 5.2.1 of IEC 61156-1 and should have a nominal diameter between 0,5 mm and 0,65 mm. A conductor diameter of up to 0,8 mm may be used if compatible with connecting hardware

Table 3 *(2 of 2)*

ETB Inter consist physical layer interface			
OSI Layers	**Requirements**	**Type**	**Description**
	Segment performance	M	Segment (D-class) includes cables, connectors, and port devices – EMC IEC 62236-3-2 for immunity and emission referred to rolling stock apparatus; Criteria acceptance type A: During test, Frame Loss Rate (FLR shall be below a trigger value. To be defined depending on application. – Ethernet Certification compliant to ISO/IEC 11801 (conformance test category) • Cables shall be compliant with Clause 9 • Connectors shall be compliant with Clause 10; The Telecommunication outlet (TO) is the inter-Consist connector instead of the RJ45 • Channel shall be compliant with Clause 6 Channel comprises sections of cable, connecting hardware, work area cords, equipment cords and patch cords.
	Consist orientation Reversing	C	Refers to the change of orientation of a Consist In order to provide Consists reversing capability, physical connection between two Consists requires two lines (see Figure 4 below).

It has to be noted that the number of connectors on a physical Ethernet segment and the length of the cable are not indicated in the table. Instead, a minimum requirement of electric performance and compliance to ISO/IEC 11801 is defined. It means that the electric parameters of a cabling depend not only on the number of connectors and the cable length, but also on some more complex parameters like shield, type of connectors, quality of cabling, installation, etc. As a consequence, it is proposed a global concept of verification in being compliant to the electric Ethernet parameters ISO/IEC 11801.

Figure 4 below illustrates the Consist reversing connection constraint: connectors shall be placed on Consist extremities with a central symmetry. When using male/female connectors, they shall be placed in an alternate / inversed way and be an even number.

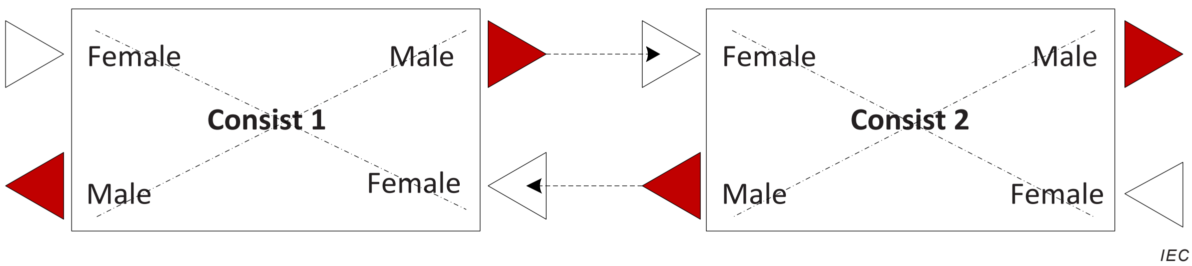


Figure 4 – ETB Consist reversing

For information only:

Typically, the same potential between 2 Consists cannot be ensured. In this case, the interruption of the Ethernet cable shield could be required (see Figure 5).

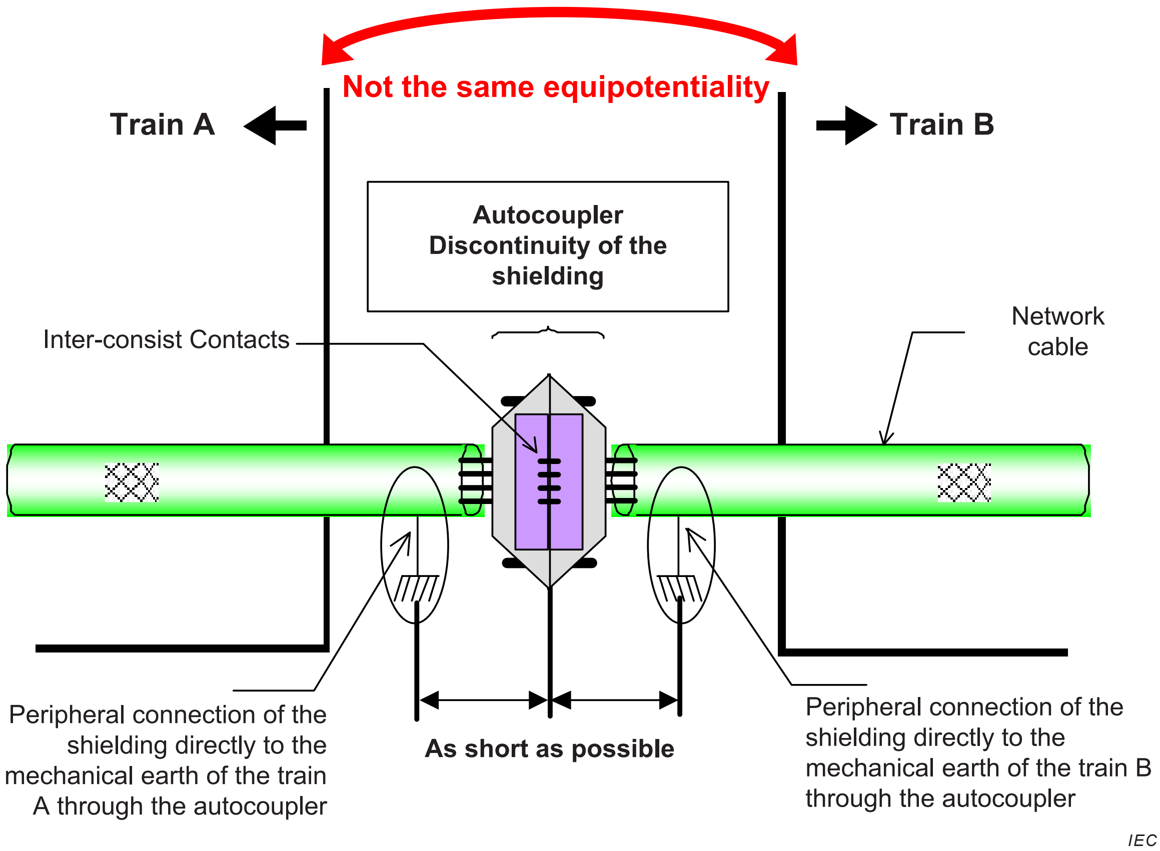


Figure 5 – ETB Inter Consist segment

NOTE The implementation of the shielding solution is not in the scope of this standard.

4.3 Power over Ethernet (PoE)

Figure 6 and Figure 7 give some use cases of PoE usage in ETBN:

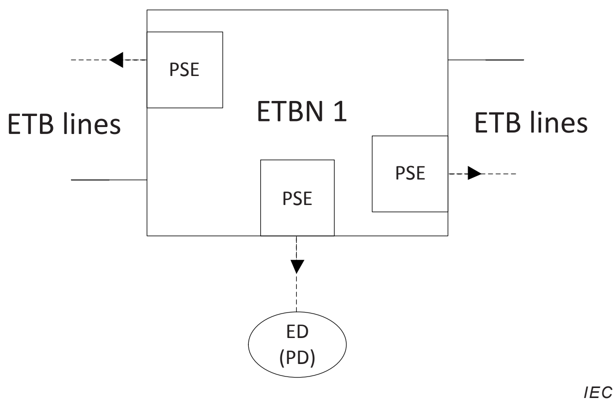


Figure 6 – ETBN PSE PoE use case

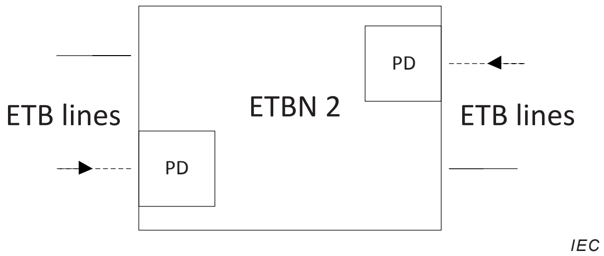


Figure 7 – ETBN PD PoE use case

In intra-car PoE could be used to power an ED (CCTV, etc.). The ND Ethernet port acts as a PSE (Power Source Equipment).

In inter-car and inter-Consist, PoE could be used to power a ND. A PSE interface shall be connected to a PD interface. In case of ETB link redundancy, PSE and PD interfaces shall be alternated in order to keep a symmetrical rotation of car (see Figure 8 below). PSE interfaces shall be associated with female connectors and PD interfaces shall be associated with male connectors if male/female connectors are used for inter-Consist interface (see Figure 4).

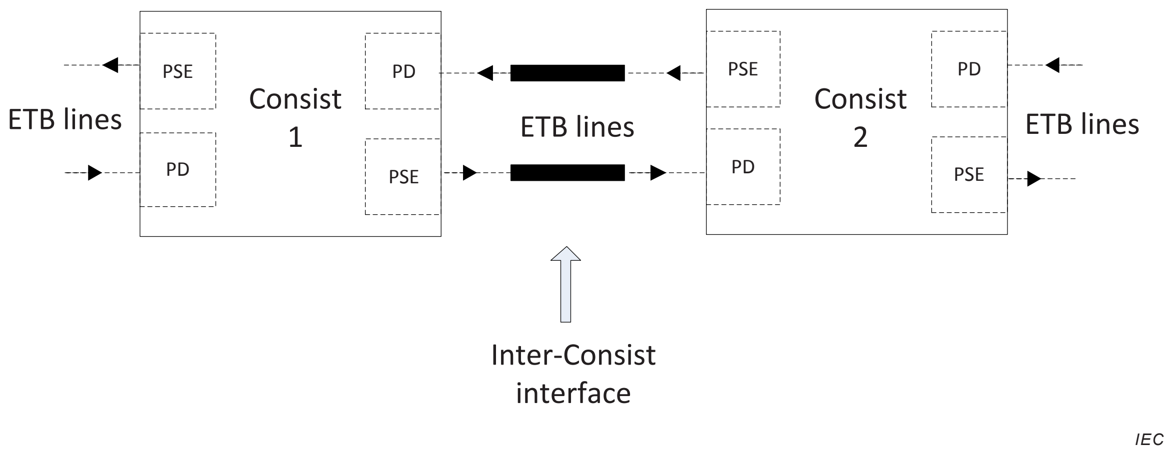


Figure 8 – PoE in inter-Consist

Figure 9 shows the connection between PSE and PD. The alternative A of PoE IEEE 802.3 Clause 33 shall be used because only two pairs are used (Tx/Rx).

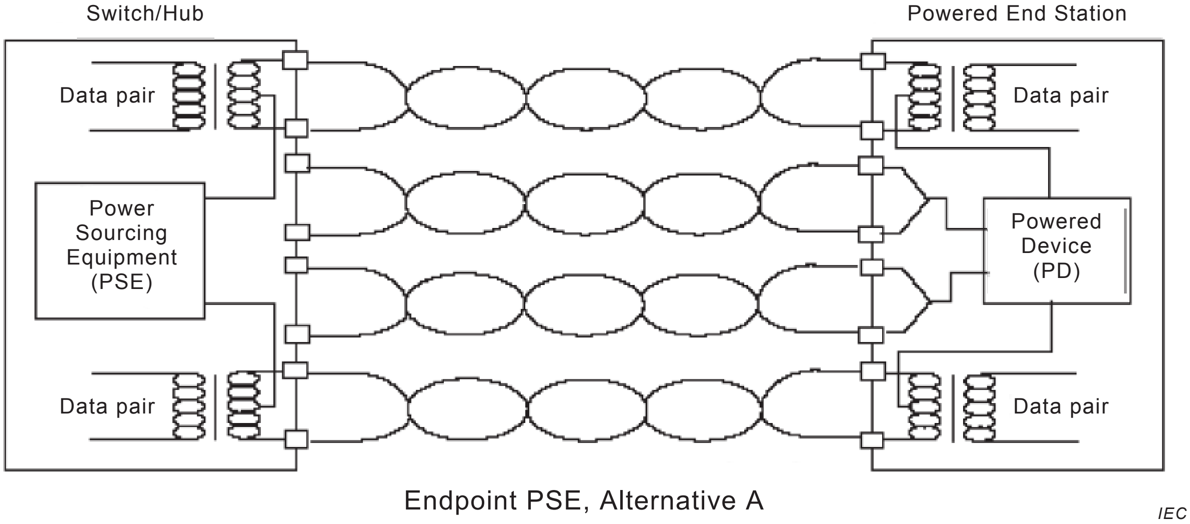


Figure 9 – PoE PSE alternative A

4.4 ETB physical architecture and redundancy

4.4.1 General

IEC 61375-1 describes the general architecture applicable to ETB, with an optional requirement of redundancy (see 5.2.3 “Train Backbone based on switched technology“). An illustration is shown on Figure 10 below:

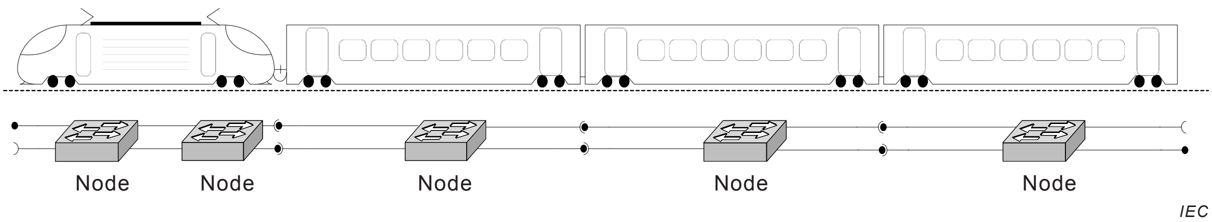


Figure 10 – Redundant train backbone architecture

The general requirements for the ETB physical layer architecture are the following:

- As a switched technology is used, nodes shall provide a data transmission medium to each of their direct neighbour nodes, if present. Each ETBN has at least one ETB forward port and one ETB backward port statically defined.
- When optional redundancy is required, data transmission medium shall be at least doubled.
- Even without redundancy requirement, the link between 2 ETBNs shall be doubled using normal switch ports when Consist reversing capability is required. Physical connection between two Consists needs two cables in this case (see 4.2.4).
- A bypass relay function shall bridge a node if the node is powerless or not operating.

4.4.2 Link aggregation architecture

When there are multiple lines between 2 ETBNs (e.g. when redundancy or Consist reversing is required), link aggregation layer from IEEE 802.1AX shall be used.

As having a single, non-redundant line for ETB communications can be considered as a degraded mode of link aggregation, it will be assumed (and so described) in the rest of the this standard that link aggregation is used.

Link aggregation described in IEEE 802.1AX is managed at OSI layer 2, and allows one or more lines to be aggregated together to form a logical group, able to manage the link redundancy (see Figure 11 below).

Link aggregation combines several individual lines, each having a physical and MAC layer. From the MAC client, a single MAC interface is provided.

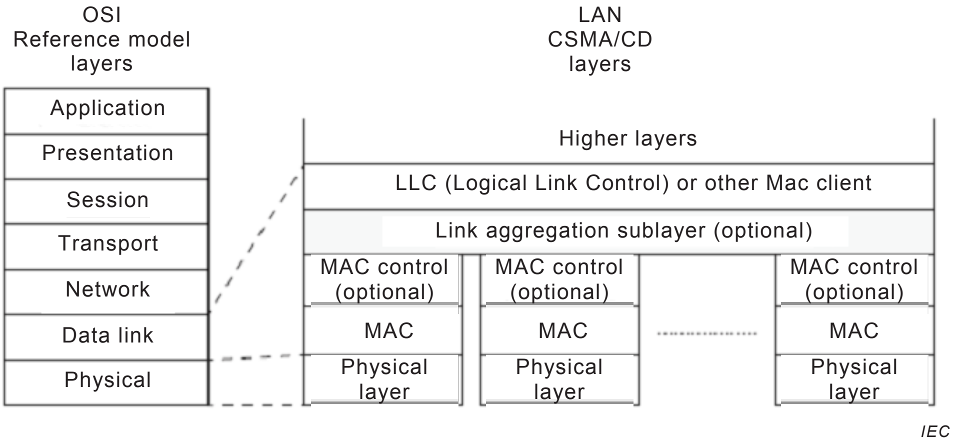


Figure 11 – Link aggregation model

On an ETB node, up to four physical ports are allowed to provide redundancy for a communication link, and will be defined as a link aggregation group (also called hereinafter logical link).

When Consist reversing is required, for symmetry reasons (see 4.2.4), 2 or 4 physical lines shall be used in each aggregation group. As stated before, the special case of a single line (no symmetry needed when Consist reversing not required) is considered as a degraded mode of link aggregation. So, a link aggregation group on ETB may contain 1, 2 or 4 physical lines.

Between 2 ETB nodes, there is only one link aggregation group which contains the redundant Ethernet segments. The link aggregation process is only defined as a relation between 2 ETB nodes.

In some cases, due to the specific railway context, some repeaters could be placed on lines between two ETBNs (e.g. to regenerate electric signal). This requires the use of a protocol that can take into account this architecture (see Figure 12 below and 4.4.3.2), because the only use of the “line status” becomes insufficient: only a frame exchange can solve this problem. According to IEEE 802.1AX, the usual way to perform this function is to implement LACP (Link Aggregation Control Protocol). For this ETB specification, and in order to limit network load, instead of using LACP, line port status are managed by Train Topology Discovery Protocol (TTDP) described below using LLDP frame with a specific organizational HELLO TLV (TTDP HELLO frame).

A logical link is usable as long as at least one of its physical lines is ok (as in standard link aggregation). The degraded state information of a link when it loses a physical line can be retrieved by SNMP.

An intermediate repeater Network Device shall transfer LLDP frames without any change between these two interfaces.

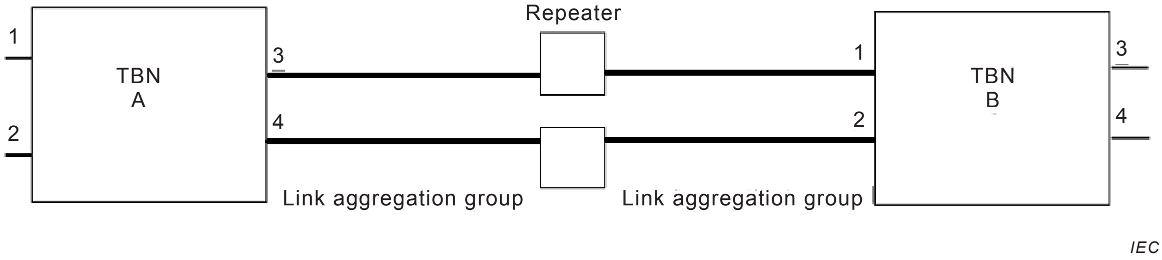


Figure 12 – Link aggregation group

NOTE Link aggregation supports the way to optionally add ports and lines between ETBNs, in order to improve reliability and performances (allocating more bandwidth).

4.4.3 Functions

4.4.3.1 Data flow principles

A load sharing is supported on the train backbone, meaning that MAC client traffic is distributed across the lines.

IEEE 802.1AX does not specify any particular distribution algorithm. To ensure interoperability between different systems, this algorithm shall cause neither disordering of any given conversation (TCP, IP, etc.), nor duplication of frames.

Each conversation uses only one line at a time. This ensures the interoperability between 2 train nodes even with different algorithms. Figure 13 below illustrates different conversations, but each on the same line:

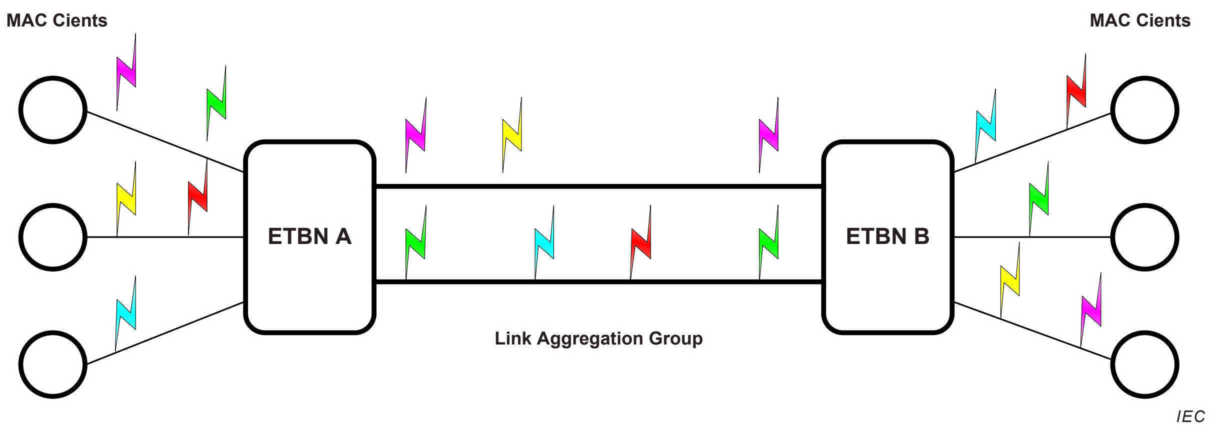


Figure 13 – Conversations over LAG

4.4.3.2 Configuration

Link aggregation configuration is set statically at initialisation time of ETBN. Configuration shall follow link availability. Link logical status is computed using TTDP HELLO frame and Ethernet port status.

4.4.3.3 Reconfiguration

The reconfiguration of the redundant lines shall be made in case of change of physical connectivity (failover). The link aggregation process shall quickly converge to a new configuration of the redundant lines in a time below or equal to 200 ms (see 8.9.1).

Reconfiguration is managed by TTDP HELLO frames and ETB ports statuses.

4.4.3.4 Compliance

Backwards compatibility with aggregation unaware communication devices shall be supported. Lines that cannot take part in aggregation shall operate as normal.

Link aggregation shall never add or change the content of frames exchanged between devices.

Compliance is defined in PICS, coming from IEEE 802.1AX:2008, 5.7.

5 ETB data link layer

Table 4 summarizes network data link layer requirements for a switch device connected to the train backbone subnet.

(M: Mandatory, O: Optional, C: Conditional, X: Prohibited)

Table 4 – ETB Switch data link layer interface *(1 of 2)*

ETB Switch data link layer interface			
OSI Layers	**Requirements**	**Type**	**Description**
Application Presentation Session Transport Network **Data** Physical	MAC services and addressing IEEE 802.3	M	
	LLC services IEEE 802.2	X	802.3 Ethernet frames with Ethernet II framing used (with 16-bit EtherType field)
	Frame Relaying IEEE 802.1D PICS A.7	M	Frame reception, Frame transmission, Forwarding process which comprises: Queuing, QoS Priority mapping, FCS calculation,etc.
	Frame Filtering (layer 2 filtering) IEEE 802.1D, Clause 7, PICS A.8	M	Learning process, Filtering data base (Mac addresses, ports, VLAN association), static/dynamic entries
	Frame Queuing IEEE 802.1D, 7.7.3, 7.7.4 PICS A16- Annex G	M	Multiple traffic classes (TC) for relaying frames; assign ingress frames a defined priority.
	Frame tagging/untagging IEEE 802.3, 3.5, IEEE 802.1Q (VLAN)	M	Ethernet frames can be tagged during switch port ingress. The tag can then remain within the frame or can be removed during port egress.
	VLAN Services IEEE 802.1Q (VLAN), PICS A.21	M	Helps subdividing the physical LAN in different virtual LANs.
	Port mirroring	O	Configures one switch port to mirror the traffic from another switch port.
	Flow Control IEEE 802.3, Part 2 Annex	O	
	Ingress rate limiting (policing)	O	Limit the reception rate of selected incoming frames
	Egress rate shaping	O	Limit the transmission rate of selected outgoing frames

Table 4 (*2 of 2*)

ETB Switch data link layer interface			
OSI Layers	**Requirements**	**Type**	**Description**
	Spanning Tree Protocol (STP), Rapid Spanning Tree Protocol (RSTP) IEEE 802.1D	X	
	Link Aggregation IEEE 802.1AX	C	NOTE To manage ETB link redundancy Link Aggregation is mandatory TTDP HELLO frames shall be used to manage link group.
	LLDP protocol Link Layer Discovery Protocol IEEE 802.1AB	M	Used by Train Topology Discovery Protocol between trains.
	Management and Remote Mgt IEEE 802.1D, Clause 14 PICS A.14, A.15	M	Configuration of the switch, Fault management (detection / diagnostic / correction), Performance management (statistics, bandwidth measurement capability). Only supported on managed ND.

6 ETB network layer: IPv4 subnets definition

6.1 General

Table 5 summarizes network layer requirements for all devices connected to the train backbone subnet.

(M: Mandatory, O: Optional, C: Conditional)

Table 5 – ETB OSI Network layer

ETB OSI Network layer			
OSI Layers	**Requirements**	**Type**	**Description**
Application Presentation Session Transport **Network** Data Physical	ARP Address Resolution Protocol IETF RFC 826	M	
	IPv4 Internet Protocol IETF RFC 791	M	
	Hostname	M	Name of ED, shall be unique in its owner Consist whatever the ETBN is connected to. Should be statically defined: read from a local permanent memory, an external coding key, etc.
	Default Domain Name	C	If DNS client is enabled, shall be set to "ltrain" Should be statically defined: read from a local permanent memory, an external coding key, etc.
	IPv4 address	M	In range 10.128/9 (see 6.4.2). Dynamically defined following Inauguration (see 6.5.2).

Table 5 (*2 of 2*)

ETB OSI Network layer			
OSI Layers	**Requirements**	**Type**	**Description**
	IPv4 mask	M	255.255.192.0
	IPv4 static routes	O	Could be used to ground communication or other Consist sub-subnets access. Could be statically defined.
	IPv4 DNS address	C	If DNS client is enabled, shall be set to IPv4 address of the DNS server.
	Management of IP Differentiated Services Field (DSCP: Differentiated Services CodePoint Field) IETF RFC 2474	O	Application should be able to set DSCP IP field to set traffic priority.

6.2 IP mapping introduction

The following paragraphs describe mandatory and minimum network IP addressing definitions to ensure communication interoperability between open trains.

Open trains are composed of Consists from heterogeneous origins, this standard gives minimum requirements to connect them together.

No hypothesis is done about how to put in place IP mapping (how to set IP address), only IP address plan is described (for Ethernet application inside Consist, see IEC 61375-3-4).

6.3 Topology

6.3.1 General

As described in IEC 61375-1, Consist topology shall be hierarchical with one or more train backbone subnet (ETB, Ethernet Train Backbone) and one or more Consist Network subnets (see Figure 14).

ED (End Device) could be connected directly to ETBN (Ethernet Train Backbone Node).

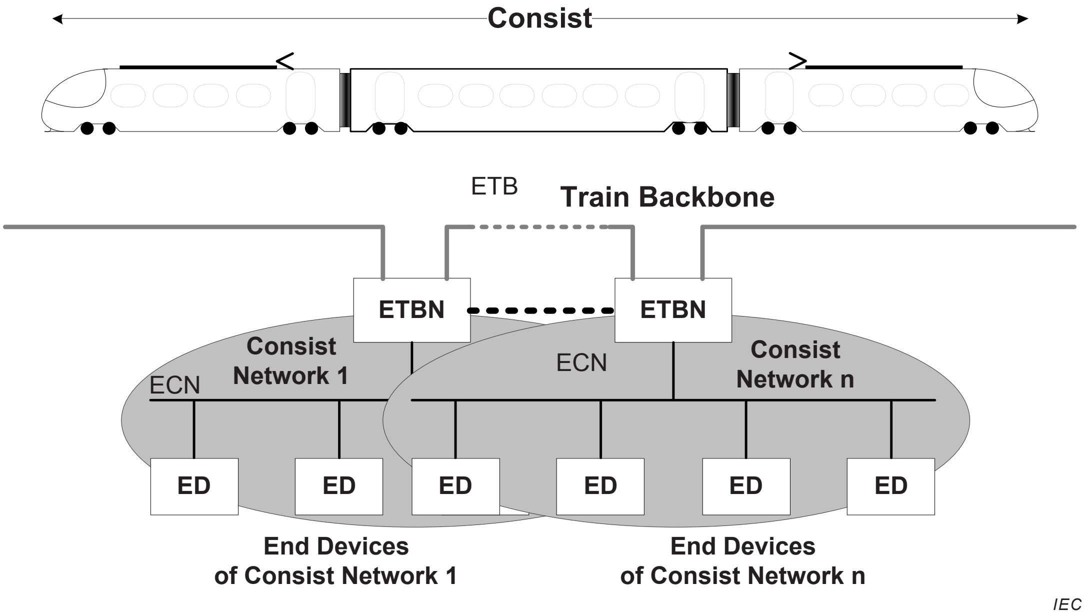


Figure 14 – Hierarchical Consist topology

NOTE 1 The following paragraphs suppose that ETB OSI layer 1 (connectors, cables,etc.) and layer 2 interfaces are interoperable.

NOTE 2 Due to hierarchical topology, Consist network interoperability interface is localized between ETBN (Ethernet Train Backbone Node) on ETB subnet.

NOTE 3 On ETB subnet, links redundancy is assumed at OSI layer 2, without requirements at IP level definition (see IEEE 802.1AX Link Aggregation).

NOTE 4 Inside a train, after initialization and Inauguration process, any communication device (ED, ETBN,...) should be joined by an unambiguous IP train address.

NOTE 5 IP address mapping could be the same between different open trains. Each open train is considered as a little independent private network.

NOTE 6 Local internal Consist traffic is out of interoperability scope.

6.3.2 Closed train

The definition of a closed train according to IEC 61375-1 is a train composed of one or a set of Consists, where the configuration does not change during normal operation, for instance metro, suburban train or high speed train units (see Figure 15).

Additional Requirements from operators regarding Closed Trains are:

– Flexible composition of Closed Trains, i.e. varying number of intermediate cars.
– Automatic configuration without commissioning.
– Addressable as a unit from inside and from outside of the unit.

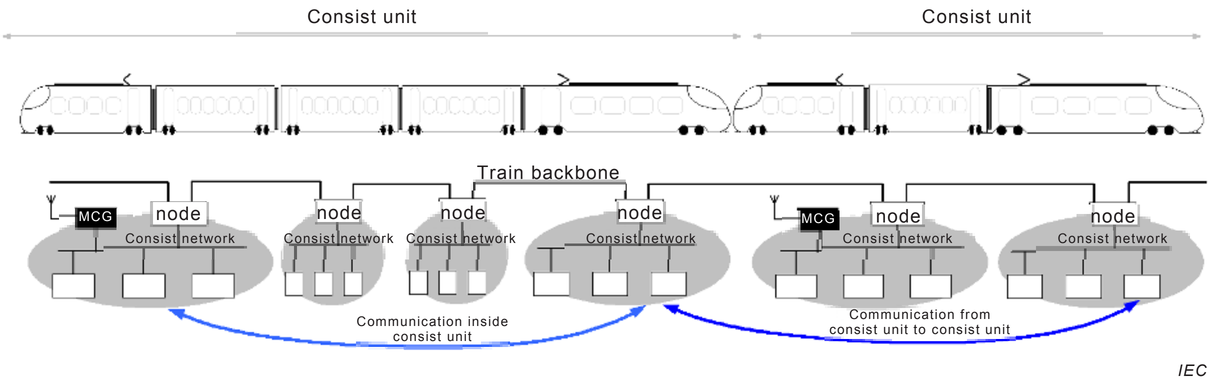


Figure 15 – Closed train

To support closed train architecture, the same CstUUID shall be used for all Consists which constitute the closed train. At ETB level, a Closed Train can be seen as a single "virtual Consist" with its associated CstUUID and the Consists which form the Closed Train are not seen as Consists anymore when integrated as an IEC 61375 interoperable Closed Train. Closed train internal description is out of the scope of this standard and is specified in IEC 61375-2-3: communication profile.

6.4 Network IP address map

6.4.1 Global IPv4 address space

First rule is to use inside the train, IPv4 address space **10.0.0.0/8**, reserved by the Internet Assigned Numbers Authority (IANA) for private network (see IETF RFC 1597, Address Allocation for Private Internets for more details).

Second rule is using CIDR (Classless Inter-Domain Routing) capability, according to IETF RFC 1519, to define subnets (split and/or aggregate).

6.4.2 Train subnet definition

6.4.2.1 General

To not use all 10.0/8 address space and reserve a range for local communication usage or supplier specific usage, train subnet address space is limited to **10.128.0.0/9** (see Table 6).

00001010.**t**xxxxxxx.xxxxxxxx.xxxxxxxx/9

Table 6 – Train subnet definition

[t]	Notation	Description
0	10.0.0.0/9 or 10.0/9	localized subnets
1	10.128.0.0/9 or 10.128/9	train subnets

Localized subnets address space could be used to define local subnets: inside a Consist, on ETB level, outside the train, etc. This address space is free of use and out of interoperability scope.

6.4.2.2 Train subnet decomposition

Train subnet (t=1) is split using following rules:

00001010.1**bbxssss.ss**hhhhhh.hhhhhhhh/18 with fields explained in Table 7:

Table 7 – Train subnet decomposition

Subnet number part:	
[b]	« Backbone Id », between[0,3]. Identify some train backbone subnets. Up to 4 ETB could be defined. Statically assigned, wiring rules between Consist shall ensure good connection between same ETB backbone. This Id is not dynamically computed during Inauguration phase. 0, for TCMS 1, for multimedia 2, not specialized 3, not specialized
[x]	« reserved bit ». Shall be clear (x = 0).
[s]	« Subnet Id », Inauguration result, identify each Consist network subnet (CN) of the train. Null value is reserved for the train backbone subnet (ETB).
Host number part:	
[h]	« Host Id », unique host identification inside CN, up to 16 382 hosts by Consist. Some upper bits could be used to define internal dedicated Consist subnets. In this case, address mask (at CN side) should take into account this decomposition and shall be extended.

As consequences:

- ETB0 (TCMS) Ethernet Train Backbone subnet is 10.128.0.0/18
- Broadcast IP address on ETB0 is: 10.128.63.255

6.4.2.3 CN identification, « Subnet Id »

6.4.2.3.1 General

To identify each Consist Network subnet (CN) inside a train, a “Subnet Id” value is necessary. This value is determined using results of Inauguration process (see TTDP, Clause 8). “Subnet Id” is coded as an unsigned integer with 6 bits precision. Null value is reserved for ETB and shall never be returned by Inauguration process. Up to 63 CN subnets could be defined inside a train.

After Inauguration, each ETBN is also numbered, from 1 to n, from one end of the train (top ETBN node) to the other (bottom ETBN node). The result is an “ETBN Id” with 6 bits precision, inside [1..63] range. Null value is excluded and shall never be returned by Inauguration process (in fact, inside a single Consist, minimum number of ETBN is one). Up to 63 ETBNs could be connected on ETB.

Do not confuse “Subnet Id” and “ETBN Id”. “Subnet Id” identifies a CN subnet inside the train, where “ETBN Id” identifies an ETBN on the backbone.

Both values, “Subnet Id” and “ETBN Id” are used to build train IP addresses.

6.4.2.3.2 Single Consist Network (CN) per Consist

When a Consist is composed of only one Consist Network subnet without ETBN redundancy, “Subnet Id” is equal to the “ETBN Id” (see Figure 16 and Figure 17).

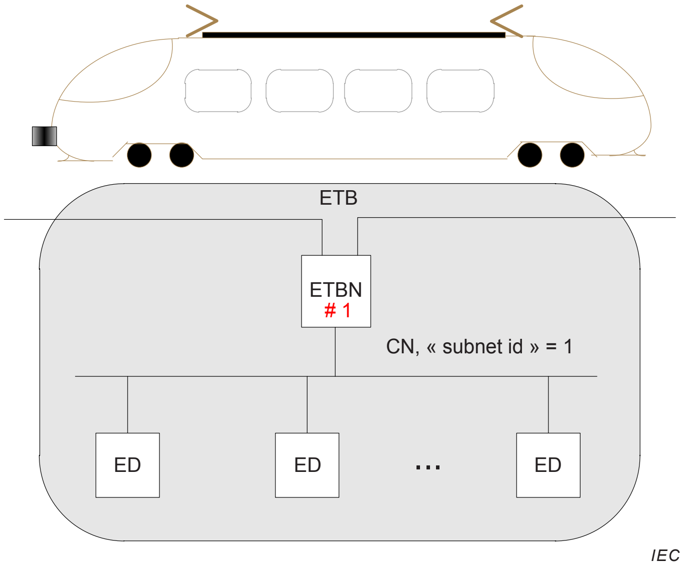


Figure 16 – "Subnet Id" with single Consist Network

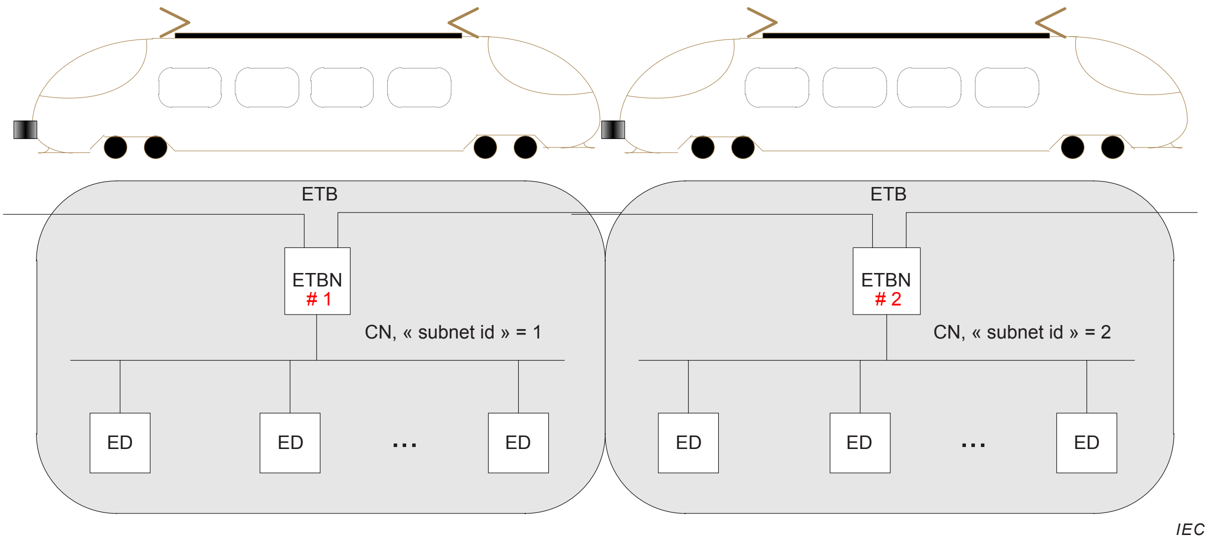


Figure 17 – "Subnet Id" with two single Consist Networks

6.4.2.3.3 Multiple CN per Consist

As many Consist network subnets (CN) could be present inside a same Consist (more than one ETBN by Consist), "Subnet Id" value follows ETBN numbering in the same order (see Figure 18).

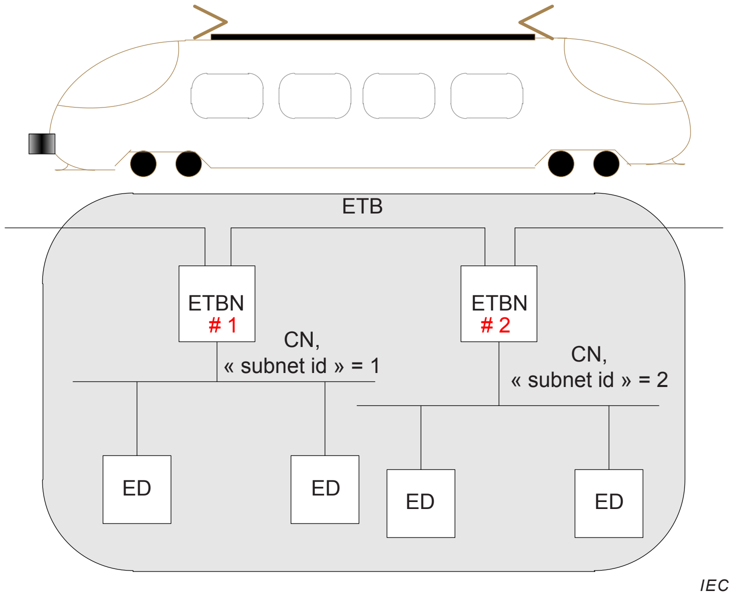


Figure 18 – Multiple Consist Networks, without fault tolerance

6.4.2.3.4 ETBN redundancy

In case of ETBN redundancy, two ETBN connected to the same Consist network subnet, have two “ETBN Id” but shall share the same “Subnet Id” (see Figure 19).

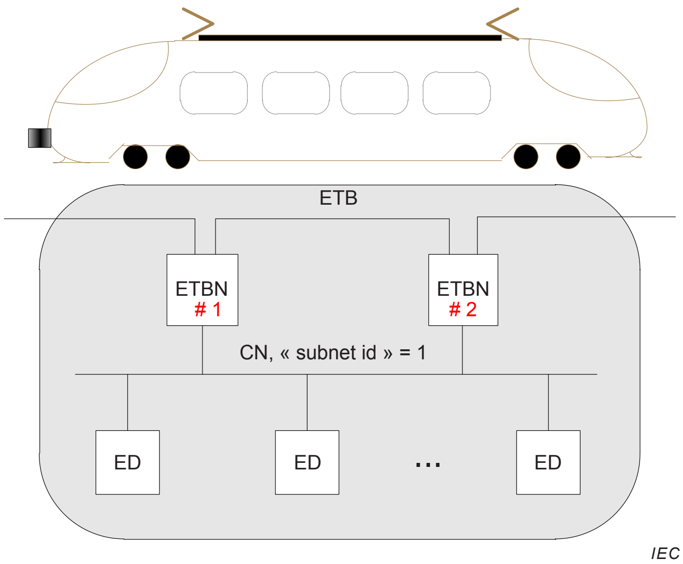


Figure 19 – "Subnet Id" with ETBN redundancy

Depending on configuration and train composition, “Subnet Id” shall be incremented following CN subnet occurrence in the same order as ETBN numbering (see Figure 20).

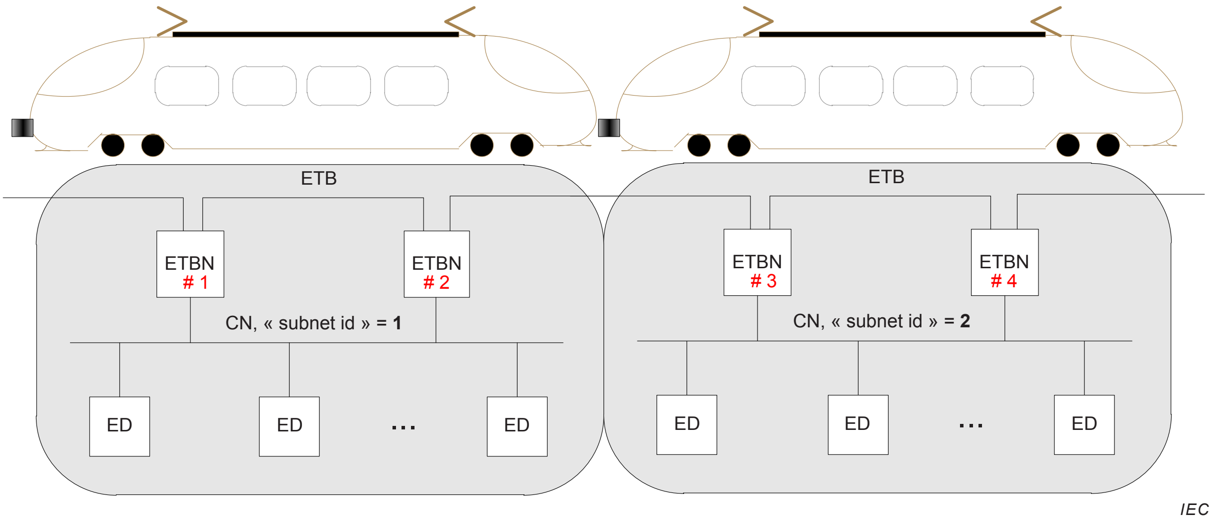


Figure 20 – "Subnet Id" in multiple units with ETBN redundancy

6.4.3 Train IP address map summary

Train IP address map is summarized in Figure 21:

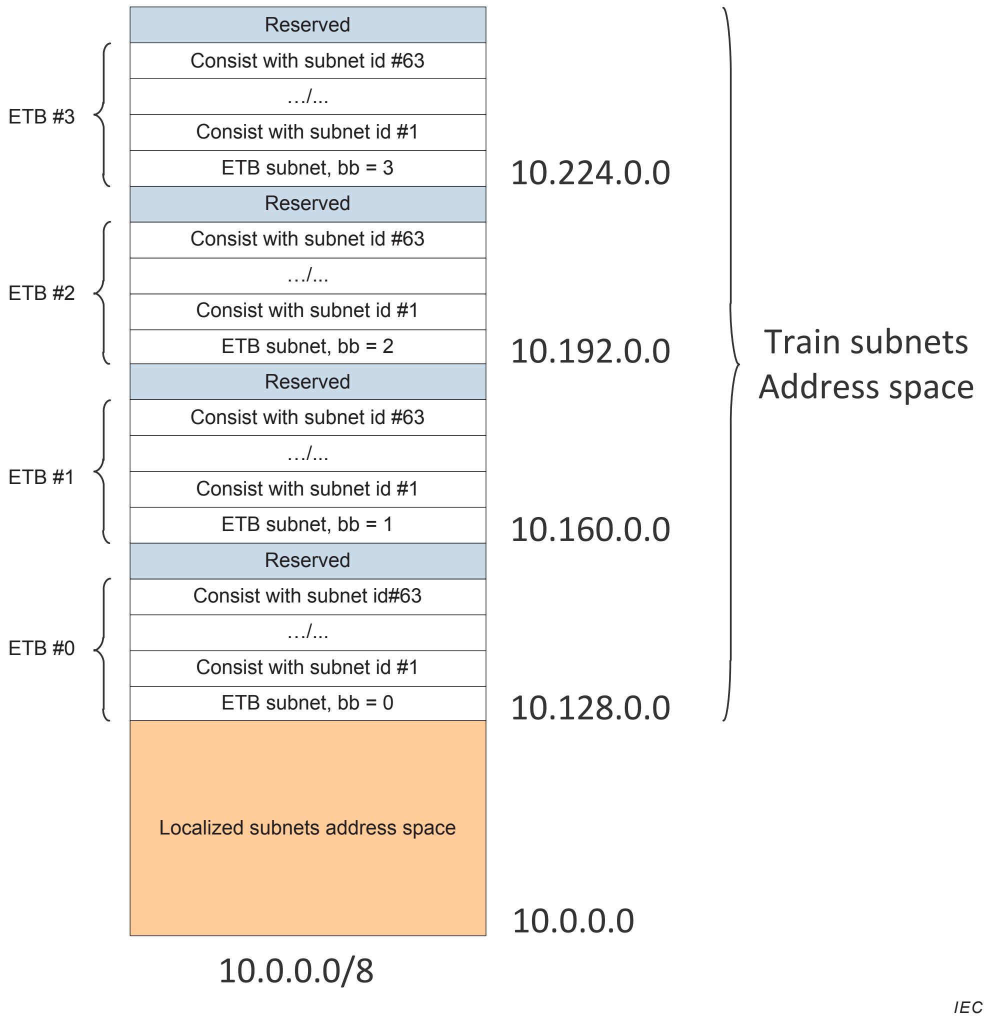


Figure 21 – IP train address space summary

6.4.4 Train IP group addresses (multicast)

At train level, IETF RFC 2365 range **239.192.0.0/14 (organization scope)** shall be used for multicast addressing (see Table 8).

When CN is based on Ethernet (ECN) another multicast address range should be defined for local ECN usage, proposed range is **239.255.0.0/16 (local scope)**, see IETF RFC 2365 and IEC 61375-3-4.

Interoperability reserved range is (255 group addresses):

239.192.0.0 to 239.192.0.255

Table 8 – Train IP group addresses reserved range

Group	Description	Routable
239.192.0.0	All Consists: enables addressing all nodes of all Consists	Yes
239.192.0.X	All hosts on Consist in position X according to Train Network Directory, X between 1 to 63	Yes
239.192.0.64 to 239.192.0.127	Reserved for future use (ex.: leading, lead Consist)	Yes
239.192.0.128	All hosts on ETB subnet	No
239.192.0.129	All ETBN on ETB subnet	No
239.192.0.130 to 239.192.0.255	Reserved for future use	No

So:

- All ETBNs shall subscribe to 239.192.0.129.
- All hosts on ETB subnet shall subscribe to 239.192.0.128.
- EDs needing to receive train scope messages shall subscribe to 239.192.0.0.

6.5 Particular hosts IP addresses

6.5.1 ETBN (Ethernet Train Backbone Node)

6.5.1.1 General

If CN subnet attached to ETBN is IP based (this is the case for ECN), ETBN has at least two interfaces and takes two train IP addresses, one on ETB side, and another on CN side.

NOTE 1 As a same ETBN could be used to connect multiple CNs, an ETBN could have multiple IP addresses, one on ETB side, and one on each connected CNs.

NOTE 2 If ETBN is used to directly connect several EDs on the backbone (acting as a switch), ETBN has only one IP address on ETB side.

6.5.1.2 ETBN ETB IP address

ETBN IP addresses on ETB side are defined as follows:

00001010.1**bb**00000.00000000.**v0tttttt/18** with fields described in Table 9:

Table 9 – ETBN ETB IP address

Subnet number part:	
[b]	« Backbone Id », between[0,3]. Identify some train backbone subnets. Up to 4 ETBs could be defined. Proposal: 0, for TCMS 1, for multimedia 2, not specialized 3, not specialized
Host number part:	
[v]	« Virtual Bit », if set, defines virtual IP address for ETBN redundancy.
[t]	« ETBN Id », Inauguration result, it is the ETBN number inside the train. Never Null, between [1,63]. If "Virtual Bit" is set, "Subnet Id" shall be used in place of "ETBN Id".

6.5.1.3 ETBN CN IP address

Train IP address of ETBN on CN side is like any Consist ED IP address and follows CN subnet definition (see 6.4.2.2). ETBN host part number could take any value.

As common convention, ETBN train IP host part number should be set to 1 for the master or virtual router.

6.5.2 Hosts on train subnet

In case of ETBN acts as a switch, EDs can be connected on ETB. They have to take a train IP address inside ETB subnet, like ETBNs. This standard defines only an IP address range. The method to set IP addresses for such devices is left open but shall not generate extra ETB traffic. Up to 254 hosts by ETBN could be directly connected on ETB.

Host IP addresses on ETB side are defined as follows:

00001010.1**bb**00000.00**tttttt**.hhhhhhhh/**18**

with fields described in Table 10:

Table 10 – Hosts IP on train subnet

Subnet number part:	
[b]	« Backbone Id », between [0,3]. Identify some train backbone subnets. Up to 4 ETBs could be defined. 0, for TCMS 1, for multimedia 2, not specified 3, not specified
Host number part:	
[t]	« ETBN Id », Inauguration result, it is the ETBN number inside the train. Never Null, between [1,63].
[h]	« Host Id », unique host identification for this ETBN node. Range [1,254] due to 254 hosts maximum by ETBN node available.

6.5.3 Host inside a closed train

6.5.3.1 General

In case of use of closed train, additional addressing plan can be put in place in order to address communication needs inside the closed train.

Such an addressing plan provides to an ECN host an IP address to join another host in the closed train whatever the topology state is. This addressing plan shall be part of the localized subnets and out of interoperability scope.

The same constructional rules than these defined for train subnet definition shall apply.

To identify each Consist Network subnet inside the closed train, a “Closed train Subnet Id” value is necessary. This value is determined during train preparation dynamically with private protocol or statically as closed train topology does not vary in normal operation.

“Closed Train Subnet Id” is coded as an unsigned integer with 6 bits precision. Null value is reserved to closed train backbone Subnet Id. Up to 63 CN subnets could be defined inside a closed train. During closed train composition, a direction number (1 or 2) is allocated to each closed train end.

Each ETBN is numbered, from 1 to n inside the closed train, from direction 1 to direction 2 of the closed train. The result is a “closed train ETBN Id” with 6 bits precision, inside [1,63] range.

6.5.3.2 IP relative addressing plan (optional)

Consist networks are enumerated in consecutive way during inauguration. Due to the linear structure of the ETB, each Consist Network can be addressed by a specific offset from the local Consist Network.

When trains are coupling or uncoupling, only new Consist Networks appear or existing Consist Networks will disappear, but the offsets of the remaining Consist Networks do not change. So the relative addressing is not affected by address changes of the ETB as a consequence of inauguration.

An IP addressing plan relative to the local Consist Network can be defined as below:

00001010.0sstoooo.oodddddd.dddddddd /12

with:

s 0..3, scope (3 = train, 2 = closed train, 1 = Consist, 0 = Consist Network; currently relative IP addresses are only defined in the train scope)

t 0..1, type (0 = absolute, 1 = relative; always 1 for relative IP addresses)

o 0..63, offset of the destination Consist Network

d 1 .. 16383, device address

This addressing plan is relative to the local Consist Subnet Id to which the end device belongs. The same addressing plan is available at each Consist Network level but according to the position of the Consist Network inside the train, it identifies different Consist Networks.

The offset of the destination Consist Network is calculated according to the following rule:

O = (Consist Network Id of source device – Consist Network Id of destination device + 64) mod 64

By convention, it is assumed that the ETB node belongs to the local subnet and that its offset is equal to 0. Its IP relative address is:

00001010.01110000.00000000.v0tttttt/18

with:

[v]	« Virtual Bit », if set, defines virtual IP address for ETBN redundancy.
[t]	« Closed train ETBN Id », configuration result, it is the ETBN number inside the closed train. Never Null, between [1,63]. If “Virtual Bit” is set, “closed train Subnet Id” shall be used in place of “ETBN Id”.

Due to the use of localized subnet address space for the relative IP address, the ETBN shall implement a NAT mechanism in order to convert the relative IP address.

The ETBN of the source device shall convert:

a) the relative destination IP address to a train wide IP address,

b) the source IP address to a relative source IP address regarding the orientation of the ETBN of the destination device.

NOTE All destination IP addresses at ETB level belong to the train subnet address space 10.128.0.0/9. The relative source IP addresses belong to the localized subnet address space.

The ETBN of the destination device shall convert:

a) the train wide destination address to the localized IP address of the destination device only,

b) and leave the source IP address as it is.

Figure 22 shows an example of the source and destination NAT in the affected ETBNs.

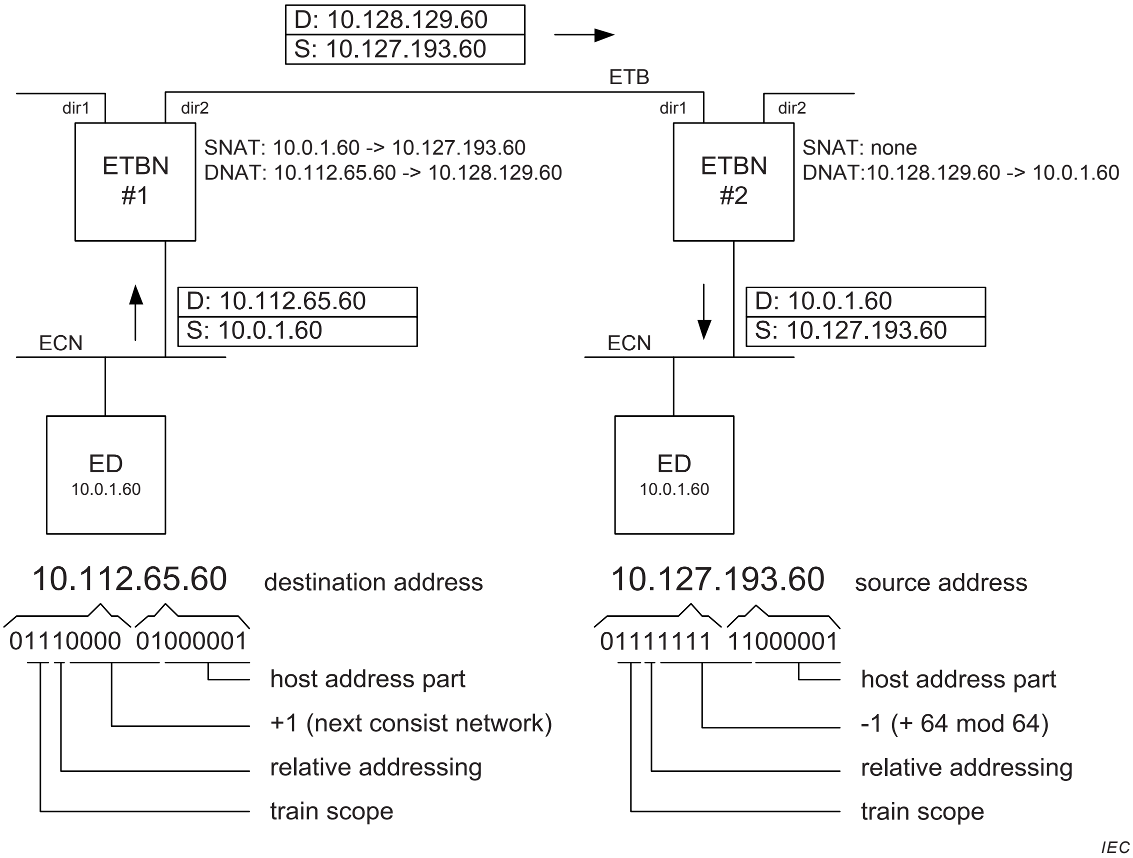


Figure 22 – Relative addressing example

The conversion of the relative source IP address in ETBN #1 takes care of the orientation of ETBN #2. Since both ETBNs have the same orientation the relative offset is converted from +1 to –1. If both ETBNs have different orientations, then the relative offset does not change. If the orientation of ETBN #2 in example (Figure 22) was reversed, then the relative source address would change to 10.112.65.60.

This addressing plan can be extended outside the closed train. In this case, due to the use of localized subnet address space, a mechanism like NAT shall be available at ETBN in order to convert localized address to train subnet address space at ETBN level. Each frame from an end device to another end device shall appear on the backbone train with destination IP address in train subnet address space. In this case, communication can be disturbed during inauguration phase as NAT mechanism depends on train topology.

6.6 Some use cases

Figure 23, Figure 24, Figure 25, Figure 26, Figure 27 show some train IP address mapping resulting from different use cases. Consist networks (CN) are not only ECNs but could use another technology: MVB, CAN,etc. All IP addresses on figures are train addresses, each ED shall have to be contacted at train level using this address (do not confuse with local IP address when CN is an ECN).

In the following, ED train IP address could be managed by ETBN or directly by ED. Ethernet Layer 2 ND (switches) are not shown.

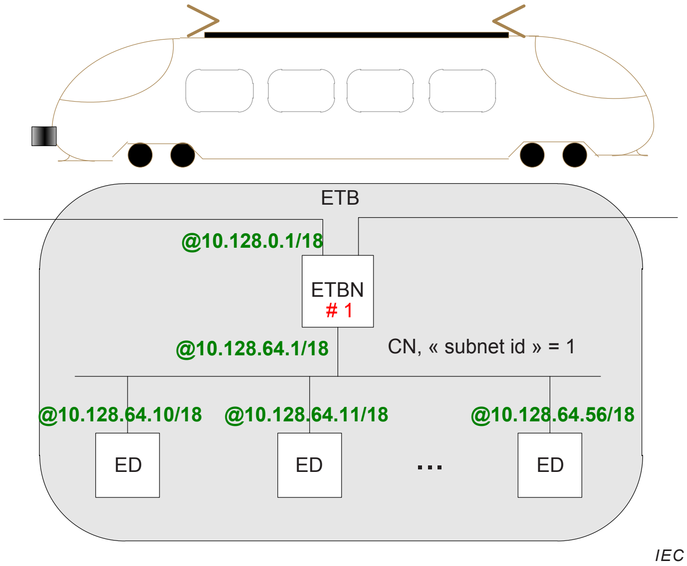


Figure 23 – Train composed of a single Consist Network

Figure 23 shows a single and simple Consist. As there is only one ETBN connected to one CN, after Inauguration (alone on ETB), ETBN takes the number 1 ("ETBN Id" = 1), and CN the number one ("Subnet Id" = 1). Using tables above, train IP mapping is deduced from these two numbers. For example, ETBN on ETB takes the IP 10.128.0.1/18. Note that, if a train IP address is associated for each ED, these ED do not necessarily manage it directly. Train IP address shall be used to address any ED inside the train (inside or outside the Consist). Conversion rules shall be defined if CN is not based on Ethernet (ECN).

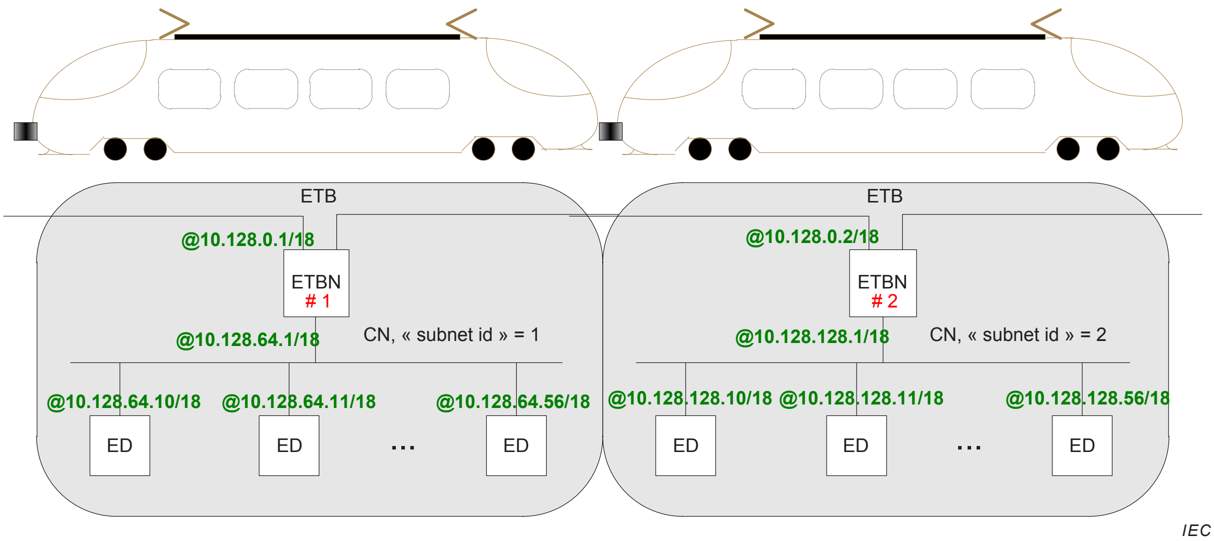
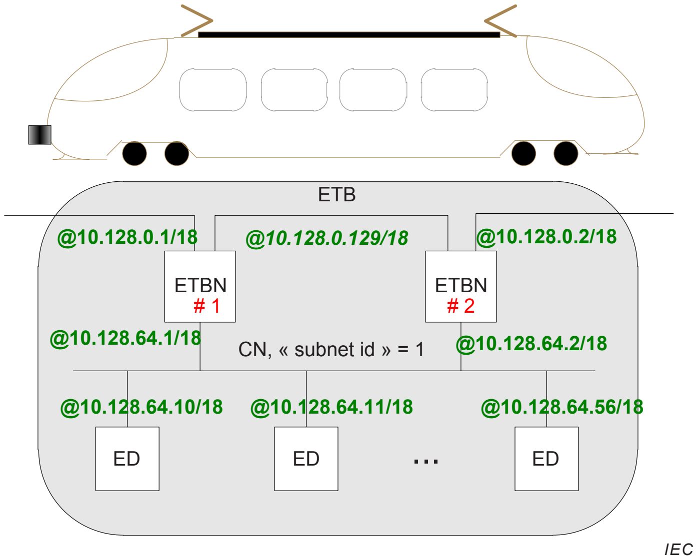


Figure 24 – Train composed of two single Consist Networks

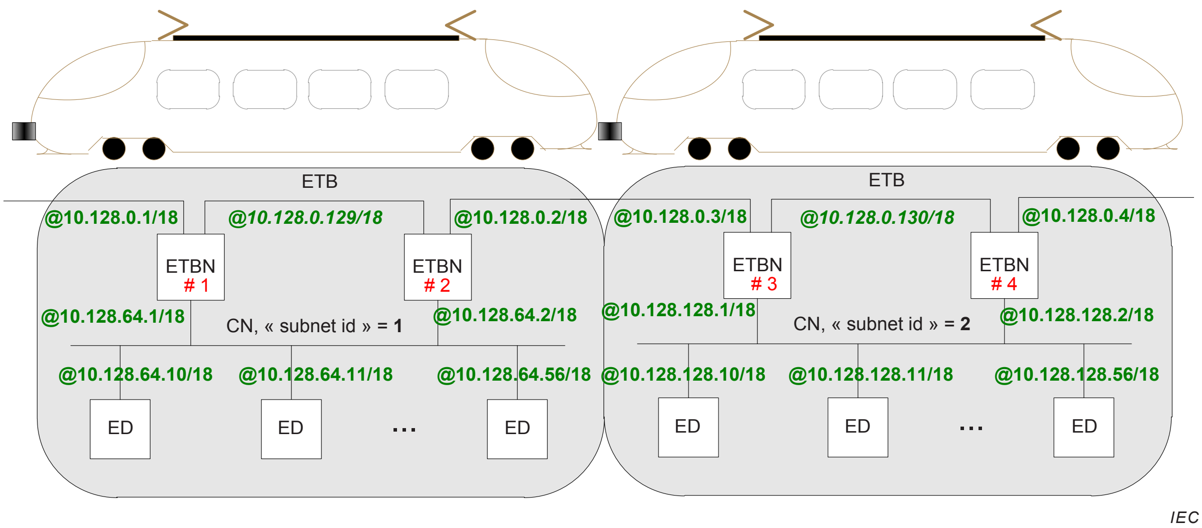
Figure 24 shows a train composed of two Consists. Each Consist includes one CN without ETBN redundancy. After Inauguration, ETBNs are numbered and take number one and two. The lowest number is affected to the train ending ETBN inside the Consist having the lowest CstUUID (see the following for more detail). CNs are also numbered in the same manner. "ETBN Id" and "Subnet Id" are used to calculate the train address mapping.



NOTE About ETBN redundancy and virtual IP address see Clause 9.

Figure 25 – Train composed of single Consist Network with ETBN redundancy

Figure 25 shows a train, limited to a single Consist, but CN is connected to ETB using both ETBNs. After Inauguration each ETBN takes a number. Number one for ETBN train ending is set by static configuration (like the "master" and "backup" role). Here, the unique CN takes the number one. Without failure, both ETBNs are active, but by static configuration one is "master" and the other "backup". The "master" defines one train IP address more: a virtual IP address (here the address 10.128.0.129/18). This single address shall be used by other ETBNs to set a route to the CN. A life sign algorithm shall take place inside CN between both ETBNs: the "backup" node asks cyclically the "master". In case of silence, the "backup" node becomes "master" and publishes the virtual IP address (a gratuitous ARP shall be sent on ETB by the new "master"). In the other ETBN, route does not change.



NOTE About ETBN redundancy and virtual IP address see Clause 9.

Figure 26 – Train composed of two Consist Networks with ETBN redundancy

Figure 26 shows a train composed of two Consists with ETBN redundancy in both. Using CstUUID, ETBN and CN are numbered. As TTDP TOPOLOGY frame describes each CN inside Consist, it is possible to give consecutive CN subnet number without hole. ETBN#3 and ETBN#4 have an IP route to the subnet 10.128.64.0/18 (CN with the "Subnet Id" = 1) using the virtual IP address 10.128.0.130/18. Respectively ETBN#1 and ETBN#2 have an IP route to subnet 10.128.128.0/18 using virtual IP address 10.128.0.129/18.

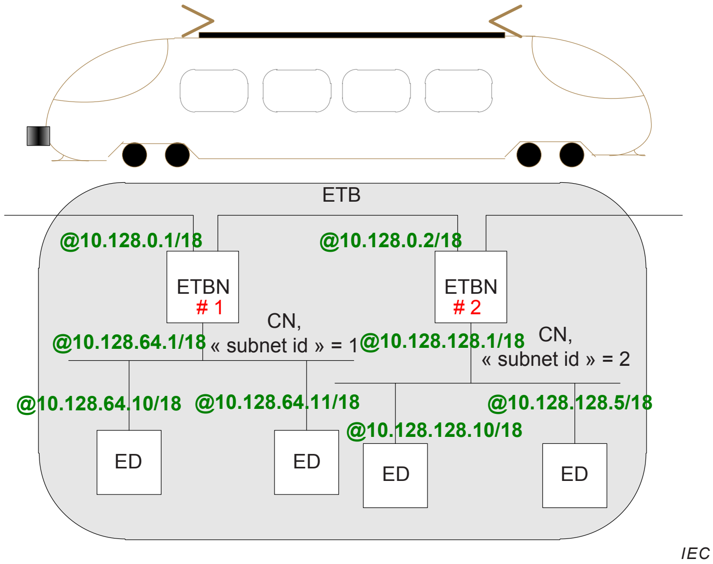


Figure 27 – Train with two Consist Networks in single Consist

Figure 27 shows a train composed of a single Consist with two CNs inside, without redundancy. ETBN#1 has an IP route to 10.128.128/18 using ETBN#2 as gateway. Respectively, ETBN#2 has an IP route to 10.128.64.1/18 using ETBN#1 as gateway.

6.7 Dynamic IP routing management

6.7.1 Unicast routes

Train Topology Discovery Protocol (TTDP) results shall be used to update IP routing table inside ETBNs.

All ETBNs are active. In case of ETBN redundancy, only the master ETBN owns the ETBN virtual IP address. This address is used by other ETBNs as gateway. See Clause 9.

6.7.2 Multicast routes

6.7.2.1 General

To forward multicast traffic between CNs, ETBNs need to be configured to do it, especially if CN is based on Ethernet (ECN).

To perform this task, multicast routing table of ETBNs shall be set. Each line of this table contains a couple of IP addresses (MG, US):

- MG: Multicast Group IP destination address,
- US: Unicast Source IP address of the multicast source address ED. US address shall be in Train subnet address range as defined in 6.4.2.1.

Multicast routing table shall be updated whenever:

- a new Inauguration occurs (to take into account new IP unicast mapping),
- an ED wants to use a new IP group destination address.

Main requirements are:

- the multicast route information shall not rely on exchanges of multicast group information provided by proprietary protocol,
- it shall take into account future functional addressing definition and PD/MD protocols where dynamic association between group address and EDs should be managed.

6.7.2.2 ETBN management

Each ETBN shall behave as a multicast router.

Multicast routers (ETBNs) shall not forward any multicast datagram with destination addresses in 224.0.0.0 to 224.0.0.255 range (224.0.0/24), regardless of its TTL.

Multicast filtering like IGMP snooping at layer 2 shall not be used on ETB network.

Multicast group addresses exchanged on the ETB shall belong to the range defined in 6.4.4.

ETBNs shall forward on ETB network all multicast group IP addresses from this specific range independently of IP source address.

ETBNs shall be aware of the list of multicast groups of interest for the end devices on its Consist Networks.

NOTE ETBNs can get this list from static configuration or through IGMP management.

For these groups, each ETBN shall install a route in multicast routing table and configure its ETB interface to accept such multicast groups.

This solution is based on the ability for each ETBN to set a line like (MG/range, *) in its multicast table.

The multicast routing table shall be flushed whenever a new Inauguration is performed. This is performed on exit of state INAUGURATED during DisableRouting action (see 8.5.1).

ETBN works as follows:

- When a frame with a multicast group address is received from an attached CN, if this group address is a member of the specified range (see 6.4.4), the frame is forwarded on ETB side.
- When a frame with a multicast group address is received from ETB, the frame is forwarded inside the CN depending on whether ED inside CN belongs to a group address inside the specific range.

7 ETB Transport layer

Table 11 summarizes transport layer requirements for a device connected to the train backbone subnet.

(M: Mandatory, O: Optional, C: Conditional)

Table 11 – Application ED common interface

Application ED Common Interface			
OSI Layers	**Requirements**	**Type**	**Description**
Application Presentation Session **Transport** Network Data Physical	ICMP Internet Control Message Protocol IETF RFC 792	M	
	IGMP v2 Internet Group Management Protocol IETF RFC 2236	M	ED shall support IPv4 multicast.
	UDP User Datagram Protocol IETF RFC 768	M	
	TCP Transmission Control Protocol IETF RFC 793	M	

8 ETB Train Inauguration: TTDP

8.1 Contents of this clause

This clause specifies the train Inauguration procedure.

Train Inauguration is based on a specific protocol: Train Topology Discovery Protocol (TTDP).

All ETBNs shall implement TTDP.

8.2 Objectives and assumptions

8.2.1 Goals

The action consisting in configuring the train network is called train Inauguration. Normal Inauguration occurs at power up time, but also when shortening or lengthening a train. To keep IP stability, Inauguration due to degraded modes shall be avoided (losing ETBN, late ETBN insertion). Best train IP configuration shall always be computed, updated and shared by all ETBNs at any time, but decision to apply it (launch of Inauguration procedure) shall always be under train application control (InaugInhibition flag, see 8.5.3).

The train Inauguration procedure needs defining an identification number for each CN subnet (“Subnet Id”) and each ETBN (“ETBN Id”). These values shall be used to build train IP mapping, train routing definition, NAT rules, ED naming, etc. (see 6.4). Computing these identifiers is the main goal of TTDP: Train Topology Discovery Protocol.

To determine these values, two types of topology are built by TTDP:

- **Physical Topology**: ordered and oriented list of ETBNs. Train physical topology is defined inside an array: the “Connectivity Table”. Physical topology is always updated to follow the number of ETBN connected to ETB. All ETBNs shall be detected (master or backup node). It can be noticed that a new physical topology does not imply a new Inauguration. To have a new Inauguration (a new IP mapping , etc.), train application shall enable it. See "corrected physical topology" in 8.8.7.
- **Logical Topology**: ordered and oriented list of train subnets. Train logical topology is defined inside an array: the “Train Network Directory”. Logical topology contains “Subnet Id“ and “ETBN Id”. It can be noticed that some identifiers are reserved by TTDP for missing ETBN or CN subnets. This can be achieved thanks to exchange of Consist CN subnet description between ETBN (see TTDP TOPOLOGY frame). A new logical topology does not imply a new Inauguration. To have a new Inauguration (a new IP mapping,etc.), train application shall enable it.

TTDP dynamically builds, updates and shares both topologies between all ETBNs. If train application enables it, a new Inauguration is launched, taking into account TTDP results to set a new train IP mapping.

The train Inauguration procedure shall respect the following rules:

– The train ETBN ending node inside the Consist with the lowest Consist UUID, is defined as the train ETBN top node.
– If train is composed of a unique Consist, ETBN top node is statically defined.
– ETBN top node takes the “ETBN Id” equal to 1.
– Subsequent ETBNs in the ETB reference direction 2 are numbered in ascending order starting with 2, the last numbered ETBN being the ETB bottom node.
– The ETB reference direction always points in the direction of the ETBN top node (see Figure 28).

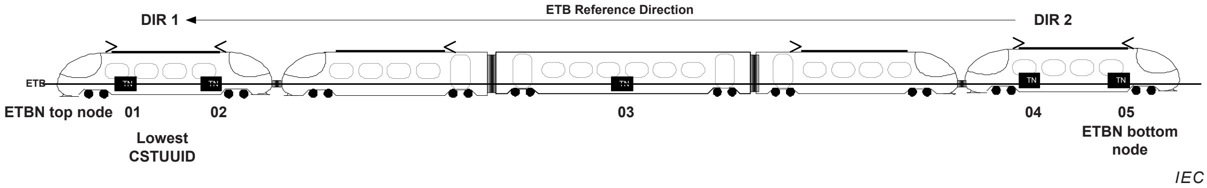


Figure 28 – ETBN top node reference

TTDP is also used to test link validity on ETB (see 4.4 for description of links).

8.2.2 Out of scope

The Consist description semantic and usage are highly project-dependent, and hence out of scope of this specification.

Physical Consist description is left outside the scope of this protocol.

Topology broadcasting to other elements inside a Consist is left outside this specification. One or several extra protocols (depending on the Consist network internal architecture) may be needed (see Clause 13).

8.2.3 Assumptions

The MOST important assumption is about the topology itself: it is assumed that ETBNs are laid out in Linear Topology. This protocol hence aims at discovering an ordered (and oriented) list. It does NOT behave properly in presence of loops and or trees, as would some routing protocol do.

Due to linear topology each ETBN will have 0, 1 or 2 neighbour peers. They will hence have notion of ‘direction’ and they shall be able to send and receive frames explicitly on each port of each side independently of link aggregation.

Each line between ETBNs is identified by a letter. As up to four lines could be aggregated, letters “A”, “B”, “C” and “D” are used.

As lines “C” and “D” are optional, in the following Figure 29 only “A” and “B” lines are represented.

Ethernet ports of ETB switch connected to DIR 1 are named “DIR1 ports”, and to DIR 2, “DIR2 ports”. Assignment of ETB ports to DIR 1 or DIR 2 is free. Association between ETB switch port identification number, direction and line can be deduced from TTDP frames.

Another assumption is the definition of the direction of an ETB switch versus static Consist direction. In order to ease train topology discovery protocol (orientation calculation), an ETB node is always in the same direction as the Consist. For installation modularity, ETB Nodes implement a static setting configuration which enables mapping ETBN ports to ETB-Direction. If an ETB node is mounted in a car which can reverse in a Consist, the ETB node direction is adjusted by modification of ETB ports and direction mapping (see Figure 29).

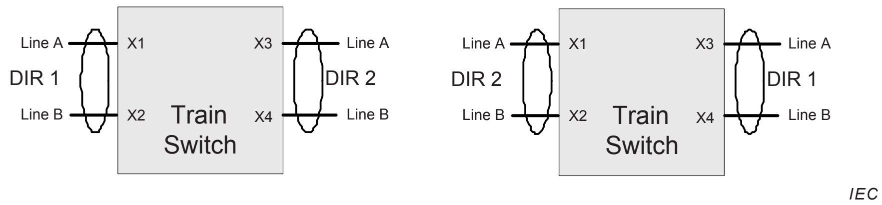


Figure 29 – ETBN orientation capability

8.3 ETBN settings

8.3.1 ETB switch port states

An ETB switch port can be in one of the states described in Table 12 (see also IEEE 802.1D):

Table 12 – ETB switch port states

Port State	Description
Disabled:	Frames are not allowed to enter (ingress) or leave (egress) disabled ports. Learning does not take place on disabled ports
Discarding:	Only IEEE 802.3 management frames are allowed to enter (ingress) or leave (egress) a Discarding port. All other frame types are discarded. Learning is disabled on Discarding ports.
Forwarding:	Normal operation. All frames are allowed to enter (ingress) or leave (egress) a forwarding port. Learning takes place on all Ethernet frames.

The following states are mandatory to implement Train Topology Discovery Protocol:

- Discarding: this state is only used for end node settings for extremity port.
- Forwarding: this state is used on all ETB ports except extremity ports.

IEEE 802.1D Learning state shall not be used on ETB nodes (in this state, only IEEE 802.3 management frames are allowed to enter (ingress) or leave (egress) a learning port. All other frame types are discarded but learning takes place on all other Ethernet frames).

Disabled state is either a temporary mode after switch power on / reset when port is used, or a permanent mode when port is statically disabled (by configuration).

8.3.2 Node settings

8.3.2.1 General

In order to support the different operational modes of train Inauguration, an ETB switch shall be configurable for the basic settings described in the following subclauses.

NOTE Only 2 lines for redundant links are represented on the figures below, but 4 lines can be used in each direction.

8.3.2.2 Passive bypass setting

In passive bypass setting, the ETB lines shall bypass the ETB switch, which then is decoupled from the ETB lines (see Figure 30). The Passive Bypass Setting is the default setting in the powerless state and the ETB switch is out of order.

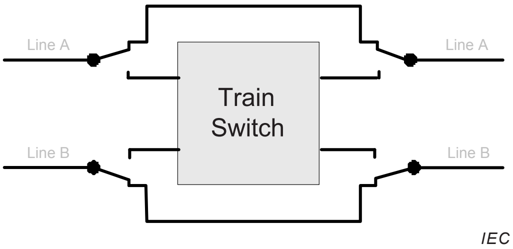


Figure 30 – ETB switch in passive bypass setting

Cabling architecture shall manage the issue of physical limit when a passive bypass is activated (increased cable length): additional switches, repeaters, etc.

8.3.2.3 Intermediate node setting

In intermediate setting, the ETB lines shall be connected to the ETB switch (see Figure 31). The ETB ports are in Forwarding state, and the ETB lines shall be aggregated in each direction in accordance to IEEE 802.1AX.

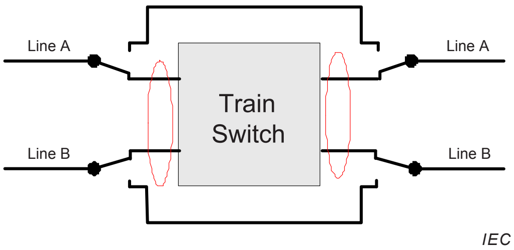


Figure 31 – ETB switch in intermediate setting

8.3.2.4 End Node setting

In End Node setting, the ETB lines shall be connected to the ETB switch (see Figure 32). Only the ETB ports in one direction (either Dir1 or Dir2) are in Forwarding state, the ETB ports in the other direction are in Discarding state (when Inauguration is completed). The Forwarding ETB ports shall be aggregated in accordance to IEEE 802.1AX. The management of Discarding port aims at protecting exchanges in an inaugurated train. ETB ports at train extremity are in Discarding state when Inauguration is completed (state INAUGURATED).

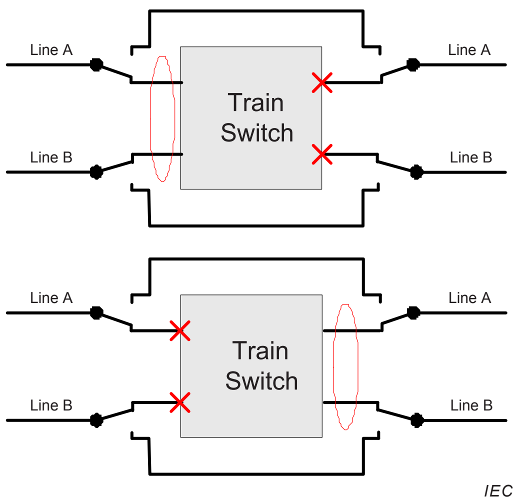


Figure 32 – ETB switch in End Node Setting

8.4 General behaviour

Inauguration process shall run on all ETBNs:

- discover and monitor ETB peers. Discovering topology process shall be always active. TOPOLOGY messages are multicast by each ETBN to all others, so ETBN switch forwarding tables are updated on each transmission;
- advertise and negotiate topology with train application. Without application acknowledge, nothing more will append;
- after application acknowledgement, train logical topology is taken into account to build train IP mapping and update network services (DHCP, DNS, NTP,etc.). EDs should be advertised of the new approved topology. Train ETB extremity ports are in Discarding state and only HELLO messages (which are IEEE 802.3 management frames) are sent and can pass through them (using management MAC address) to discover prospective coupling.

Topology stability is based on CRC calculation. When all CRCs (local one and received from other ETBNs) are the same, all ETBNs share the same topology.

The result is purely topological information: the TTDP protocol described here aims at detecting topology changes and/or stability as fast as possible. Full Consist description exchange and sharing shall be done by another protocol (see IEC 61375-2-3).

Distinction between desired changes due to train assembly/de-assembly or due to peering loss shall also be managed to avoid multiple Inauguration procedure.

8.5 ETBN Inauguration state diagram

8.5.1 General

The ETBN Inauguration process is defined by the state transition diagram on Figure 33. Definitions for this diagram are the following:

- entry: action performed once only at beginning of state
- exit: action performed once only at end of state
- do: action performed in a periodic loop
- NOT, AND, OR: logical NOT, AND, OR operators

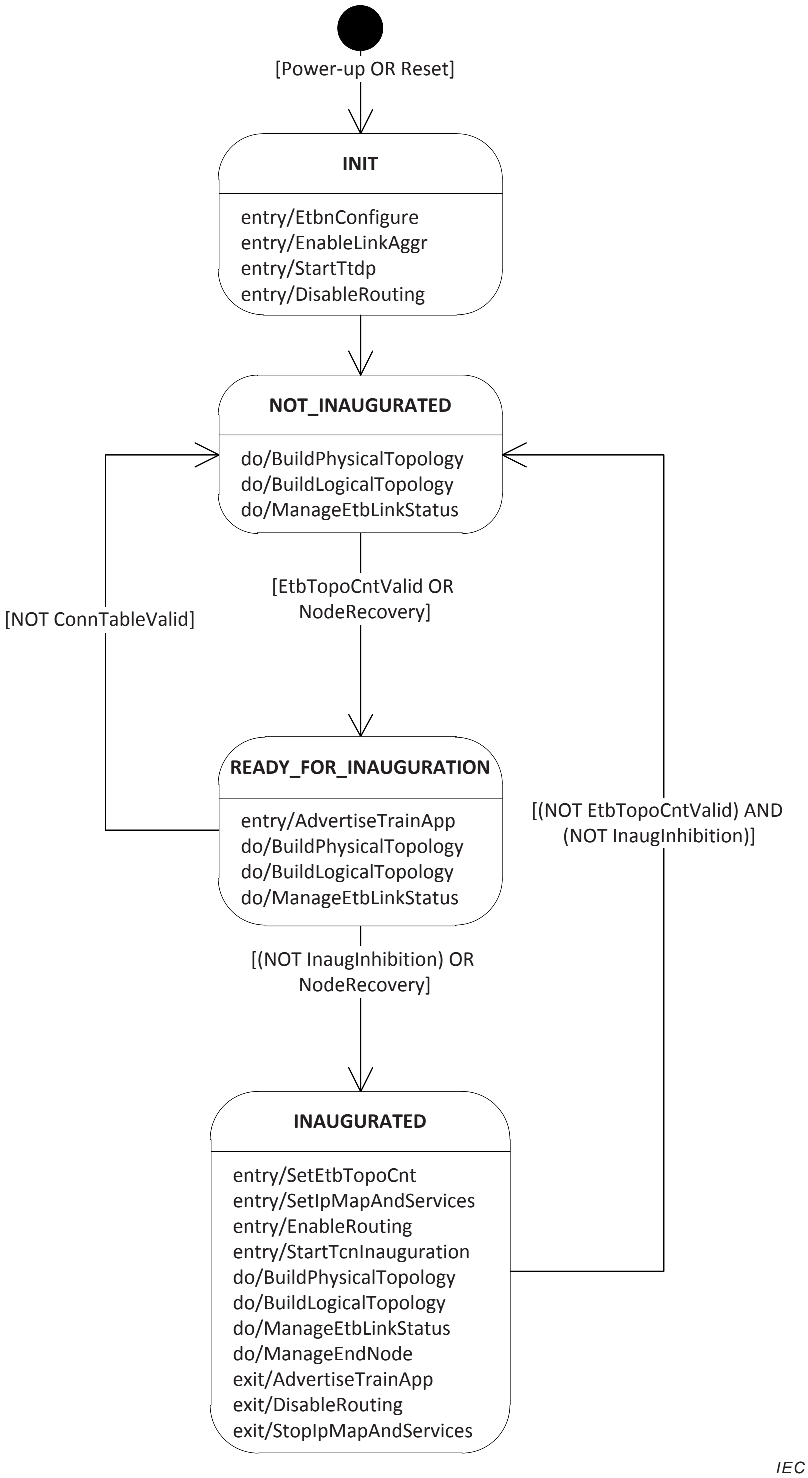


Figure 33 – ETBN Inauguration state diagram

8.5.2 Actions

EtbnConfigure

ETB switch ports are set in Forwarding state, IP forwarding is disabled, no IP configuration, ETB switch forwarding table cleared,etc.

EnableLinkAggr

DIR1 ETBN switch ports (respectively DIR2 ports) are configured to be statically aggregated together.

StartTtdp

Start TTDP daemon.

Initial Value configuration:

- ETBN ports state = "Forwarding"
- etbnInhibition = False (Inauguration is allowed at Consist level linked to ETBN)
- InaugInhibition = False (Inauguration is allowed at Train level, see description below)
- ConnTableCrc32 = "ConnTableCrc32 Default Value"
- Topology Counter = "etbTopoCnt DefaultValue"

NOTE etbnInhibition is Boolean value produced by each ETBN in TOPOLOGY frame. It is set to True when train application forbids new Inauguration (train moving in operational mode for example), set to False when train application enables Inauguration to modify all IP settings. This information is valid at local ETBN scope. At power up, etbnInhibition field in topology is set to False (Inauguration allowed).

DisableRouting

Forwarding between ETB and CN is disabled. Communication is not available between CNs.

BuildPhysicalTopology

TTDP daemon builds Connectivity Table (Physical Topology), calculates ConnTableCrc32 and updates "TTDP specific ETB" TLV in TTDP TOPOLOGY frames (see 8.7.6).

BuildLogicalTopology

TTDP daemon builds Train Network Directory (Logical Topology), calculates etbTopoCnt (see below) and updates "TTDP specific ETB" TLV in TTDP TOPOLOGY frames (see 8.7.6).

ManageEtbLinkStatus

ETBN shall manage status of ETB links with its neighbours using results of:

- TTDP HELLO frames
- Ethernet physical port status

SetEtbTopoCnt

Memorize CRC of Train Network Directory as current Topology Counter (Inauguration Identifier). While the ETB node is in state INAUGURATED, etbTopoCnt field in TTDP TOPOLOGY frame is fixed to the memorized CRC of Train Network Directory.

SetIpMapAndServices

Initialize IP mapping (all IP parameters: IP address, network mask, name resolving, IP routes, etc.) and services (DHCP, NAT, DNS, etc.) using TTDP results ("ETBN Id" and "Subnet Id"). (Re-)start services, clear ARP table, etc.

EnableRouting

Forwarding between ETB and CN is enabled. Communication between CNs is available.

AdvertiseTrainApp

New Inauguration is advertised to train application inside CN. Depending on CN technology, ETBN shall export train topology.

StartTcnInauguration

In state INAUGURATED, each ETBN shall allow TCN Inauguration to proceed as described by communication profile (see IEC 61375-2-3).

ManageEndNode

TTDP daemon manages end node identification and sets unconnected ports in Discarding state. Also, when an end node recovery has happened, this function is responsible for setting previously Discarding ports in Forwarding state (see 8.11.3).

StopIpMapAndServices

Clear IP mapping (all IP parameters: IP address, network mask, name resolving, IP routes, etc.) and stop services (DHCP, NAT, DNS, etc.).

8.5.3 Transitions

Power-up OR Reset

ETBN power on or reset event.

ConnTableValid

Boolean value, True when Physical Topology is shared by all ETBNs (same Connectivity table CRC for all ETBNs).

EtbTopoCntValid

Boolean value, True when Logical Topology is shared by all ETBNs (same Train Network Directory CRC for all ETBNs).

InaugInhibition

This flag is the result of ORing “etbnInhibition” field (considered as a boolean) of TOPOLOGY frames received from all other ETBNs and CN local value. To enable Inauguration all CNs shall enable it (i.e. all etbnInhibition flags advertised by ETBNs shall be False). At power up, InaugInhibition is not meaningful until ETBN reach at least once the INAUGURATED state (so its value at startup is set to False to allow first Inauguration).

NodeRecovery

True when own ETBN has a valid etbTopoCnt, even when TOPOLOGY frames received from other ETBNs indicate Inauguration inhibition (at least one True, in their etbnInhibition flags). This can happen when own ETBN:

- is an intermediate node, was previously a known node, disappeared and is back again,
- is an intermediate node and wakes up late in a Consist containing at least an already inaugurated ETBN.
- is a node recovering in a group of lost end nodes. A certain delay shall be waited for when going from READY_FOR_INAUGURATION to INAUGURATED: it shall be long enough (around 200 ms) so as to:

– allow the temporary end node (connected to the group of real lost end nodes) to set its temporary extremity link back from Discarding to Forwarding state (when discovering the currently recovering nodes),
– let TOPOLOGY frames be transmitted to the recovering nodes.

This delay is necessary to avoid a race condition with previously lost end nodes performing a "fast local Inauguration on their own side" (i.e. without seeing the other ETB nodes): before going from READY_FOR_INAUGURATION to INAUGURATED state, the recovering end nodes wait long enough to see again TOPOLOGY frames from other ETB nodes and converge to already inaugurated ETB topology.

8.6 ETBN peers discovery

8.6.1 Internal peers detection

Each ETBN continuously tries to detect other ETBNs on ETB. To do this, each ETBN periodically sends a multicast layer 2 frame to all other ETBNs. This frame is named TTDP TOPOLOGY frame.

Link aggregation groups (in both ETB directions) are used to send this frame.

Receiving this frame, an ETBN shall look for the source MAC address of the frame in its switch forwarding table to detect if the frame comes from the DIR1 or DIR2 side.

When ETBN is alone on ETB (it never receives frames), stability is self-declared after a delay.

A delay without receiving frame from a specific ETBN is used to detect ETBN disappearing.

Two different means can be used to build connectivity table:

- “Connectivity Vector” fields (see 8.8.1),
- “ETBN Vector” fields (see 8.8.2).

Using one or the other fields as input of topology building algorithm is free of choice, but filling all these TOPOLOGY fields is mandatory when sending TOPOLOGY frames.

Both algorithms to build Connectivity Table could be used in case of specific safety requirements.

An example algorithm which maintains physical topology is presented (for information only) in Annex B.

8.6.2 External peers detection

Once the topology is approved by train application ("InaugInhibition" flag is True), ETB Ethernet ports ending the train are set in Discarding mode. Only management frames (according to their destination MAC address) such as TTDP HELLO frames are allowed to pass through them, but TTDP TOPOLOGY frames are not.

New external ETB peers (e.g. during train coupling / ETB lengthening) will be detected by exchanges of periodical frames. These messages are named TTDP HELLO frames. But new peers will be added to ETB topology only after a new ETB Inauguration, when so allowed by train application ("InaugInhibition" flag is set to False).

These frames being quite small, they will be exchanged at some configured (high) rate, to provide good reactivity to any ETBN apparition or loss. See 8.12.2 and 8.12.3 for typical timings.

A delay without receiving TTDP HELLO frame from a known ETBN neighbour is used to detect train uncoupling (ETB shortening).

8.6.3 Switch port states handling

Figure 34 below summarizes ETBN switch port states handling according to Inauguration state and peers detection. It particularly describes how an end node can change states from Discarding to Forwarding:

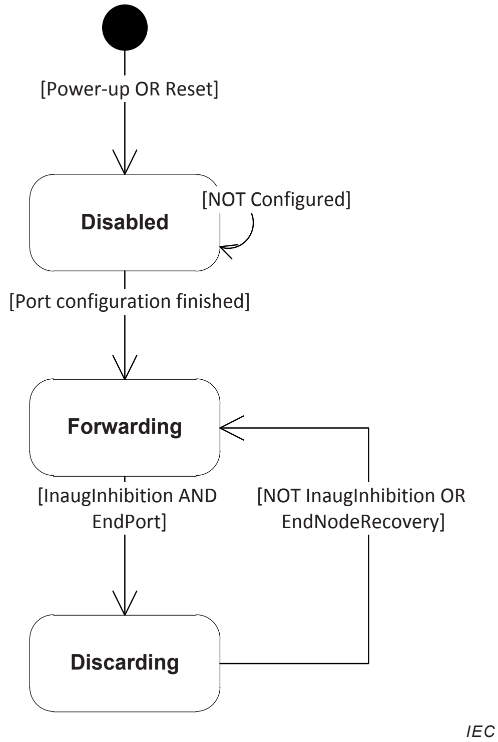


Figure 34 – Switch port state diagram

Port states definitions are given in 8.3.1.

Transitions:

- **Power-up OR Reset**: ETBN power on or reset event.
- **Port configuration finished**: port initialisation sequence after power up or reset has finished.
- **InaugInhibition**: Inauguration is inhibited when flag is True (when Inauguration is done).
- **EndPort**: port is declared as an extremity port when it receives no TTDP HELLO frames.
- **EndNodeRecovery**: port of the previously end node is reopened when another end node is discovered (for example after an end node late wake up or recovery, see 8.11.3).

ETBN ports shall be in Forwarding state after power-up before bypass relays are switched off (to connect ETBN ports to ETB lines).

NOTE When train lengthening / shortening (coupling / uncoupling) occurs, ports are reopened for new topology discovery when train application sets InaugInhibition to False.

8.6.4 ETB lines statuses

ETB lines statuses are sent in TTDP TOPOLOGY frame and shared between all ETBN (see 8.7.6).

Each ETBN computes these statuses for its own lines according to TTDP HELLO frames received on its ports (see 8.7.5). See also 8.9.1 for TTDP HELLO frames timing and timeouts handling.

The state machine for an ETBN line is shown on Figure 35 below. It is only applicable to used lines as defined by static configuration (no frames are sent on unused lines).

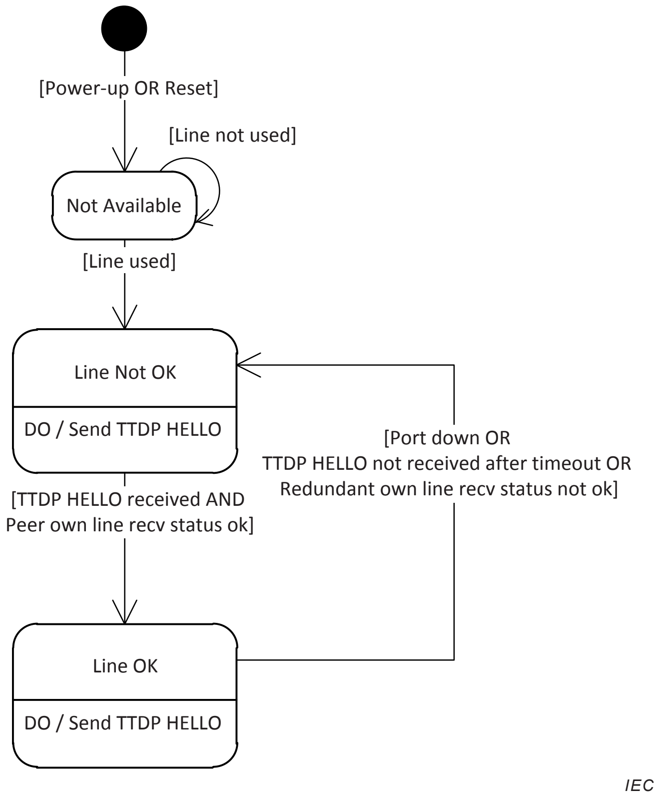


Figure 35 – ETBN physical line state machine

States:

– Line "**Not Available**" after power-up or reset or when associated switch port is configured for not being used,

– "**Line OK**" when TTDP HELLO frames are periodically received at the port switch,

– "**Line Not OK**" after start-up when line status has not yet been evaluated or when TTDP HELLO frame is not received after a given timeout at the port switch.

Transitions / conditions:

– **Power-up OR Reset**: ETBN power on or reset event,

– **Line not used**: line is statically configured for not being used,

– **Line used**: line is statically configured for being used,

– **Port down**: switch port connected to line is down.

– **TTDP HELLO received**: a TTDP HELLO frame was received within current timeout delay.

– **TTDP HELLO not received after timeout**: a TTDP HELLO frame was not received within current timeout delay.

– **Peer own recv line status ok**: the own line receive status received from remote peer in TTDP HELLO frame is ok..

– **Redundant own line recv status not ok**: the own line receive status received from one of the other redundant lines of the same aggregation group is not ok. For example, if we are looking for line A and line A receive status received from aggregated line B in TTDP HELLO frame is not ok (i.e. remote peer considers line A as not ok).

Actions:

– **Send TTDP HELLO**: in all states, when port is configured for being used, periodically send TTDP HELLO frame on associated physical line.

8.7 TTDP messages description

8.7.1 General

This subclause defines the data packets which are exchanged between the ETBNs for ETB Inauguration. There are two ETB Inauguration data packets defined:

- The TTDP HELLO frame, for the discovery of the directly connected ETB neighbour nodes and for the test of the physical communication lines to these neighbours,
- The TTDP TOPOLOGY frame, for informing all other ETBNs about the own ETB neighbour discovery. It is used for physical topology building ("Connectivity table").

NOTE Even if answers to TTDP HELLO frames are used on each ETBN to build its own "connectivity vector", this information is multicast and shared with all nodes through TTDP TOPOLOGY frames (HELLO frames are local to an ETBN direct neighbourhood).

8.7.2 Convention

The general convention for fields used in message is that:

- Unused /Reserved fields:
  - shall be set to 0 on transmission,
  - shall NOT be checked on reception.
- Byte orders
  - Numerical values spanning on more than one byte will follow the “network order” convention, which is high order bytes first.
- Numerical Values spanning on less than one byte are described assuming that the leftmost bits are the most significant byte’s bits.

8.7.3 TTDP frame tagging

TTDP messages shall be VLAN tagged in accordance to IEEE 802.1Q:

- VLAN identifier (VID) shall be set to 492 (= '1EC'H),
- VLAN priority shall be set to highest priority 7.

8.7.4 Transport and addressing

TTDP defines two specific Ethernet frames:

- TTDP HELLO frame: based on LLDP frame with a specific organizational TTDP TLV (HELLO TLV),
- TTDP TOPOLOGY frame: specific TTDP Ethernet multicast frame.

The MAC address in Table 13 shall be used for layer 2 frames:

Table 13 – TTDP destination MAC addresses

TTDP frame	MAC destination	Target	Definition
HELLO	01-80-C2-00-00-0E	Neighbour Bridge	IEEE 802.1AB, LLDP, Link Layer Discovery Protocol. Allows stations to exchange chassis and port information.
TOPOLOGY	01-80-C2-00-00-10	All Bridges	IEEE 802.1D. Defined as an ordinary multicast address to be used to reach all bridges in a bridged LAN.

8.7.5 TTDP HELLO frame

As described in 4.4.2, TTDP HELLO frames are periodically sent on all ETBN statically configured physical lines (those used for ETB).

TTDP HELLO frames (see Figure 36) are based on LLDPDU definition (see IEEE 802.1AB which contains the mandatory LLDP TLVs and organizationally specific TLVs descriptions).

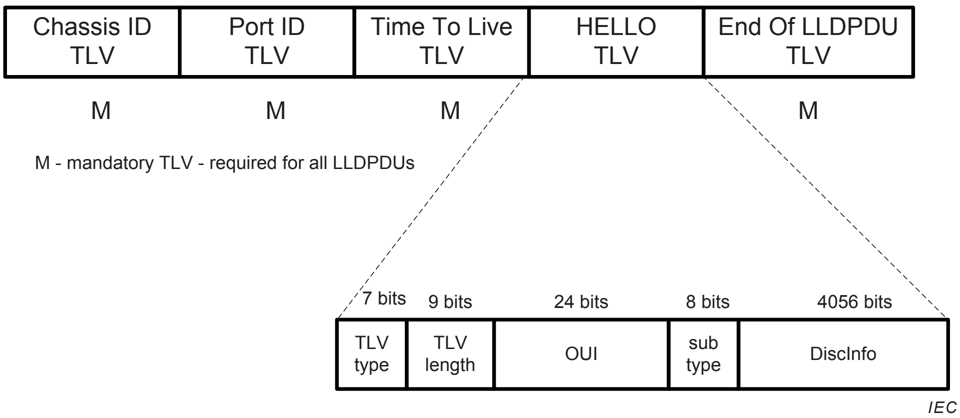


Figure 36 – TTDP HELLO frame LLDPDU structure

Mandatory LLDP TLV (Chassis ID, Port ID, TTL, EOF) are present but their values shall not be used by TTDP, so, for these mandatory LLDP TLVs, subtypes are free of use.

TTDP HELLO data are coded inside an Organizationally Specific TLV format (see Figure 37).

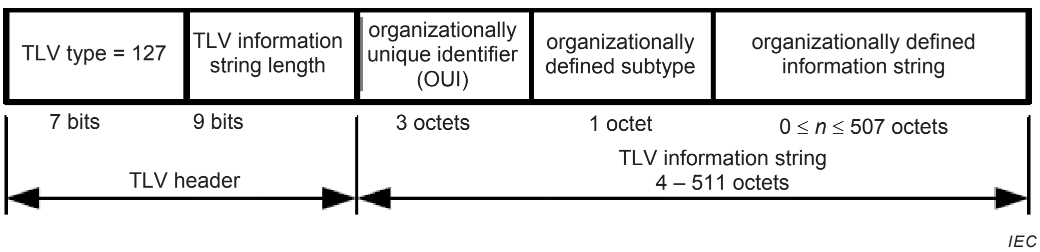


Figure 37 – LLDP organizationally TLV structure

The TTDP HELLO frame shall be defined as below in ASN.1 by TTDP-HELLO-FRAME record. Mandatory LLDP TLV subtypes are set to example values.

```
TLV-TYPE::= ENUM7 {                    -- Definition of LLDP TLV type values
      endOfLLDPDU-TLV-TYPE  (0),
      chassisId-TLV-TYPE    (1),
      portId-TLV-TYPE       (2),
      ttl-TLV-TYPE          (3),
      -- other unused values in between
      specific-TLV-TYPE     (127)            -- Organizationally specific TLVs
}

TLV-HEADER::= RECORD {                 -- Definition of standard TLV header
      tlvType              TLV-TYPE,              -- TLV type
      tlvLength            UNSIGNED9 (0..511)    -- TLV information length in octets
            -- TLV header fields are not aligned on byte boundaries,
            -- total header size is 16 bits (7 + 9)
}

GEN-TLV::= RECORD {                    -- Definition of generic TLV
      tlvHeader            TLV-HEADER,            -- standard TLV header
      tlvInfo              ARRAY [tlvHeader.tlvLength] OF WORD8
                                                  -- TLV payload
      }
}

MAC-ADDR::= ARRAY [6] OF UNSIGNED8    -- Definition of MAC address type (48-bit)

TTDP-VLAN-HDR::= RECORD {              -- Definition for TTDP VLAN header
      tpid                 UNSIGNED16 ('8100'H), -- Tag Protocol Identifier value
                                                  -- to identify the frame as
                                                  -- an IEEE 802.1Q-tagged frame
      pcp                  UNSIGNED3 (7),         -- Priority Code Point = highest
                                                  -- (refers to IEEE 802.1p priority)
      de                   BOOLEAN1 (0),          -- Drop Eligible (to indicate
                                                  -- frames eligible to be dropped)
      vid                  UNSIGNED12 ('1EC'H)   -- VLAN ID for TTDP
}

CHASSIS-TLV::= RECORD {                -- Definition of Chassis TLV
      chassisTlvHeader     TLV-HEADER {     -- Chassis TLV header values
            tlvType (chassisId-TLV-TYPE),
            tlvLength (7)
      }
      chassisIdSubtype     UNSIGNED8 ('04'H),    -- Chassis ID subtype = MAC address
      chassisId            MAC-ADDR               -- Chassis sender's MAC address
}

PORT-TLV::= RECORD {                   -- Port TLV definition
      portTlvHeader        TLV-HEADER {     -- Port TLV header values
            tlvType (portID-TLV-TYPE),
            tlvLength (2)
      }
      portIdSubtype        UNSIGNED8 ('06'H),    -- Agent circuit ID (IETF RFC 3046)
      portId               UNSIGNED8 (0..255)    -- ETB, ETBN egress physical port nb
}

TTL-TLV::= RECORD {                    -- Time To Live TLV definition
      ttlTlvHeader         TLV-HEADER {     -- Time To Live TLV header values
            tlvType (ttl-TLV-TYPE),
            tlvLength (2)
      }
      ttl                  UNSIGNED16 (0..65535) -- LLDP Time To Live (seconds)
}

EOL-TLV::= RECORD {                    -- End Of LLDPDU TLV definition
      eolTlvHeader         TLV-HEADER {     -- End Of LLDPDU TLV header values
            tlvType (endOfLLDPDU-TLV-TYPE),
            tlvLength (0)
      }
}

TIMEOUT-SPEED::= ENUM8 {               -- Definition for timeout values
      slowTimeout (1),                       -- Slow timeout value (100 ms)
      fastTimeout (2)                        -- Fast timeout value ( 15 ms)
}

LINE-IDENT::= CHARACTER8 (65 | 66 | 67 | 68 | 45)
                                 -- Definition for line identification values
                                 -- 'A' | 'B' | 'C' |'D' | '-' character ASCII codes
```

```
EGRESS-DIR::= ENUM8 {           -- Definition for directions
     dir1 (1),                            -- Direction 1
     dir2 (2)                             -- Direction 2
}

HELLO-TLV::= RECORD {           -- Specific HELLO TLV definition
     specTlvHeader   TLV-HEADER {         -- Org. specific TLV header values
          tlvType (Specific-TLV-TYPE),
          tlvLength (86)
     },
     oui             ARRAY [3] OF UNSIGNED8 ('200E95'H),
                                          -- IEC TC9 WG43 Organizationally Unique ID
     ttdpSubtype     UNSIGNED8 ('01'H),   -- TTDP HELLO TLV subtype
     tlvCS           UNSIGNED16,          -- TLV checksum(see 7)
     version         UNSIGNED32 ('01000000'H), -- HELLO TLV Version "1.0.0.0"
     lifeSign        UNSIGNED32,          -- Sequence number of packet
                                          --   always incremented and overflow
     etbTopoCnt      UNSIGNED32,          -- CRC32 checksum of the internal
                                          --  "Train Network Directory" (see 1)
     vendor          ARRAY [32] OF CHARACTER8, -- Vendor free string (see 2)
     recvAstatus     ANTIVALENT2,         -- receive status on line A (see 3)
     recvBstatus     ANTIVALENT2,         -- receive status on line B (see 3)
     recvCstatus     ANTIVALENT2,         -- receive status on line C (see 3)
     recvDstatus     ANTIVALENT2,         -- receive status on line D (see 3)
     timeoutSpeed    TIMEOUT-SPEED,       -- timeout speed (see 4)
     srcId           MAC-ADDR,            -- Source MAC address of the own ETBN
     srcPortId       UNSIGNED8 (0..255),  -- For information and diagnostic,
                                          --   ETB, ETBN egress physical port number
     egressLine      LINE-IDENT,          -- Line name ('A', 'B', 'C', 'D')
                                          -- where the current ETBN sends this frame
     egressDir       EGRESS-DIR,          -- Direction assigned to this egress line
     reserved1       UNSIGNED6 (0),       -- padding bits for 8-bit alignment
     inaugInhibition ANTIVALENT2,         -- Inauguration inhibition flag (see 6)
     remoteId        MAC-ADDR,            -- Last known MAC address of the neighbour
                                          --  (received)
     reserved2       UNSIGNED16 (0),      -- padding bytes for 32-bit alignment
     cstUuid         ARRAY [16] OF UNSIGNED8 -- Consist Universal Unique ID (see 5)
}

TTDP-HELLO-FRAME::= RECORD {     -- TTDP HELLO frame definition
     destAddr   MAC-ADDR ('0180C200000E'H),
                           --  Destination  LLDP  MAC  multicast  address  (see  IEEE
802.1AB)
     srcAddr    MAC-ADDR,              -- Source MAC address (ETBN sender's)
     vlanHdr    TTDP-VLAN-HDR,         -- TTDP VLAN header
     etherType  UNSIGNED16 ('88CC'H),  -- LLDP EtherType identifier
     chassisTlv CHASSIS-TLV,           -- Chassis TLV (LLDP mandatory)
     portTlv    PORT-TLV,              -- Port TLV (LLDP mandatory)
     ttlTlv     TTL-TLV,               -- Time To Live TLV (LLDP mandatory)
     otherTlvs1 SEQUENCE OF GEN-TLV,   -- optional list of LLDP TLVs
     helloTlv   HELLO-TLV,             -- one TTDP HELLO specific TLV in frame
     otherTlvs2 SEQUENCE OF GEN-TLV,   -- optional list of LLDP TLVs
     eolTlv     EOL-TLV,               -- End Of LLDPDU TLV (LLDP mandatory)
     etherCrc   UNSIGNED32             -- Ethernet frame CRC (see IEEE 802.3)
}
```

REMARKS

1) Calculated according to IEEE 802.3. Default value: see 8.7.5 for definition. In this TLV, its purpose is to manage recovery of temporary end node failure (see 8.11.3).

2) Vendor specific information, zero-terminated text string. Padded with null characters after the zero-terminating string character to the end of the array.

3) Receive status of line: a line receive status is ok if HELLO frames are received from the direct neighbour node on this line and if the state of the corresponding Ethernet port is up; a line receive status is considered not ok if the state of the corresponding Ethernet port is down or if no HELLO frames have been received for long + short timeout on this line. Values are the following:

   ‘00’B (ERROR) = invalid value (shall never be used)

   ‘01’B (FALSE) = receive status of line Not OK

   ‘10’B (TRUE) = receive status of line OK

   ‘11’B (UNDEFINED) = not available.

   See 8.6.4 for ETBN physical line states diagram and description.

4) Advertisement on timeout management in reception (mechanism similar to LACP) to speed failure detection in any case. This information drives the period of transmission of neighbour's TTDP HELLO frame.

   If no frame reception in slow timeout (normal) mode, then ask neighbour to go in fast transmission mode.

   Local meaning: immediate send if this field changes to advertise neighbours.

   Remote meaning: immediate send if the neighbours field changes.

   See 8.9.1 for details.

   Initial value should be set to "slowTimeout".

5) All ETBNs inside the same Consist share the same CstUUID. See below.

6) Train application status about train Inauguration authorization (global inhibition information = OR of all received ETBN local inhibition flags and local value, see 8.5.3).

   Flag value is "not available" until first topology established.

   Values are the following:

   '00'B (ERROR) = invalid value (shall never be used)

   '01'B (FALSE) = Inauguration not inhibited (Inauguration allowed)

   '10'B (TRUE) = Inauguration inhibited (Inauguration not allowed)

   '11'B (UNDEFINED) = not available.

7) TLV checksum is calculated in the same way as TCP checksum in RFC 793.

   It shall be calculated over the TLV payload (from first TLV word after the checksum to the last TLV word, both included).

   The checksum field is the 16 bit one's complement of the one's complement sum of all 16 bit words in the TLV payload (start value equals to 0). If a TLV payload contains an odd number of octets to be checksummed, the last octet is padded on the right with zeros to form a 16-bit word for checksum purposes. The pad is not transmitted as part of the TLV.

8) In case more TTDP information needs to be added to HELLO frame, a new specific TLV with the TTDP OUI should be defined. TTDP TLV with TTDP subtype $<$ 128 are reserved for interoperability and TTDP subtype $\geq$ 128 are free for specific vendor use.

CstUUID is used to uniquely identify a Consist in the world without the need of a central registration process. CstUUID is a 128 bits identifier. Its definition is done according to IETF RFC 4122. A Closed Train is seen as a Virtual Consist (see 6.3.2).

All ETBNs inside the same Consist shall have the same CstUUID.

A CstUUID is currently printed as a 32 significant digits identifier, for example:

"f81d4fae-7dec-11d0-a765-00a0c91e6bf6"

The whole TTDP HELLO frame structure can be summarized by Figure 38 below:

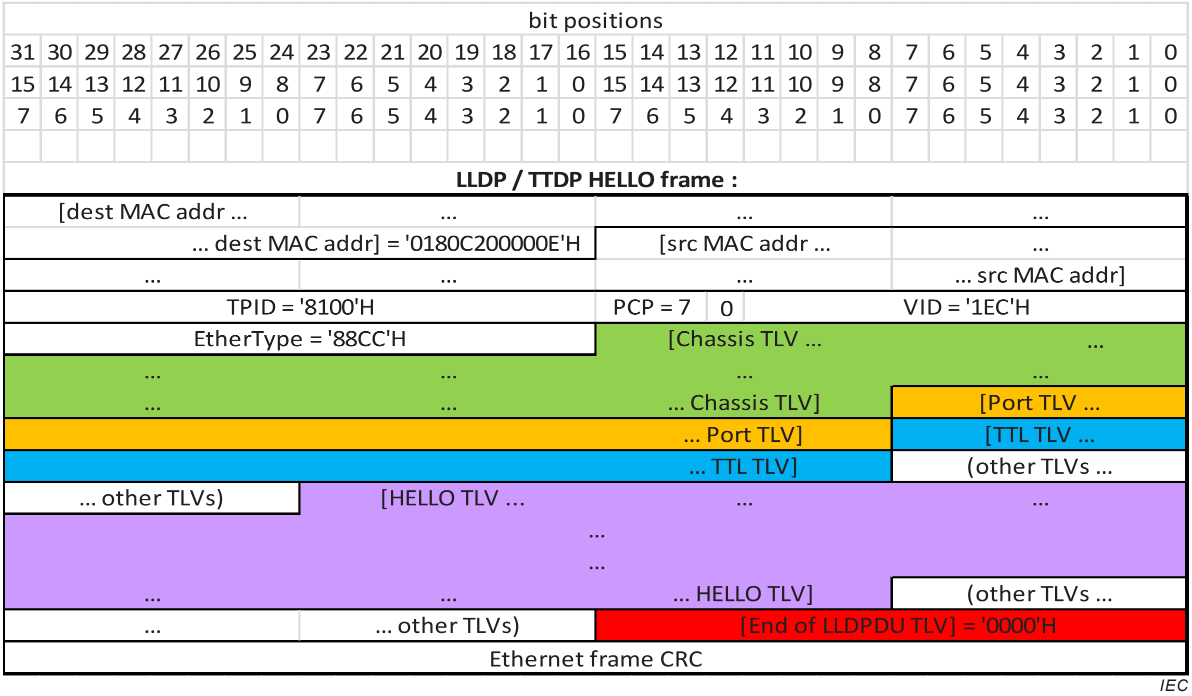


Figure 38 – TTDP HELLO frame structure

The TTDP HELLO specific TLV structure can be summarized by Figure 39 below:

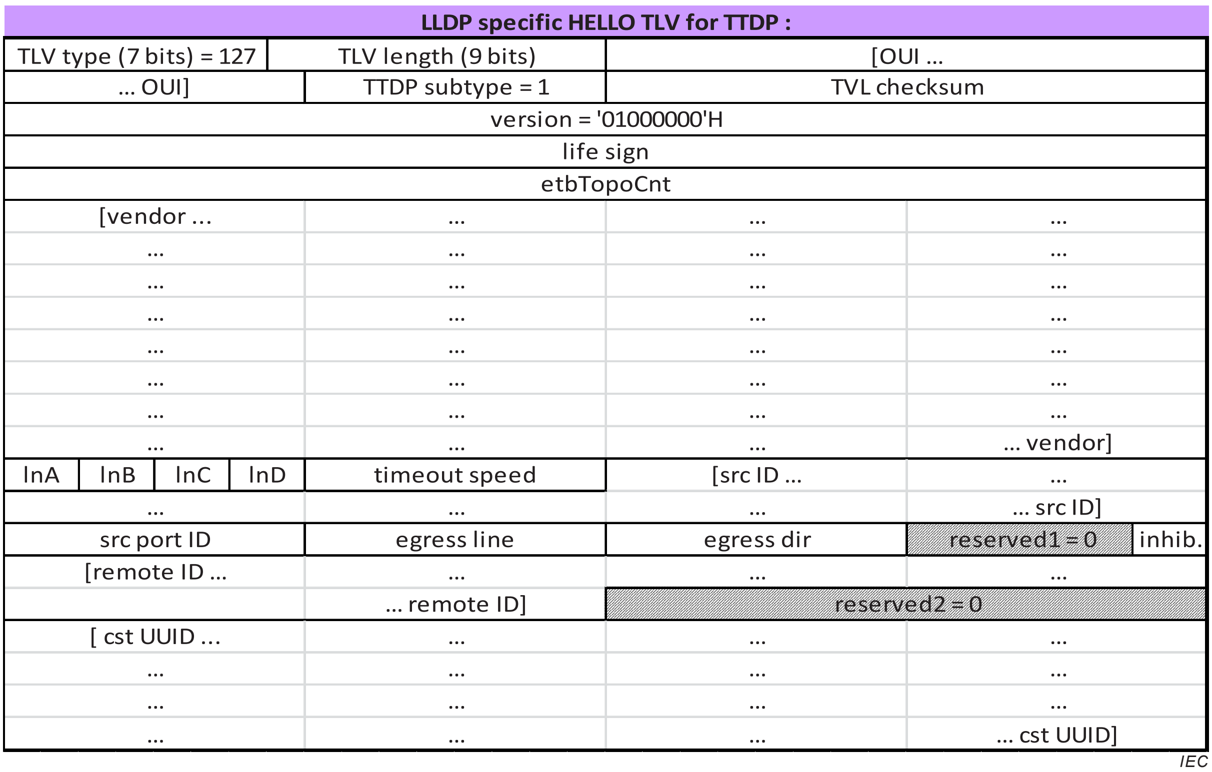


Figure 39 – TTDP specific HELLO TLV structure

8.7.6 TTDP TOPOLOGY frame

As described in 8.6.1, TTDP TOPOLOGY frames are periodically sent on all ETBN logical links (in directions 1 and 2).

These frames are used to build physical and logical topologies.

The TTDP TOPOLOGY frame shall be defined as below in ASN.1 by TTDP-TOPOLOGY-FRAME record.

NOTE Some ASN.1 definitions used below are defined in 8.7.5.

```
TTDP-PROTO-ID::= ARRAY [4] OF CHARACTER8 {84, 84, 68, 80}
      -- Definition of TTDP protocol identification string = "TTDP" in ASCII

ETBN-INAUG-STATE::= ENUM8 {      -- Definitions for the ETBN state machine
      Init             (0)
      NotInaugurated   (1),
      Inaugurated      (2),
      ReadyForInaug    (3)
      -- Other values shall never be used
}

ETBN-ROLE::= ENUM8 {                   -- Definition for ETBN node roles (see 16)
      EtbnRoleUndefined     (0),
      EtbnRoleMaster        (1),
      EtbnRoleBackup        (2),
      EtbnRoleNotRedundant  (3)
      -- Other values shall never be used
}

ETBN-DIR-LINK-INFO::= RECORD {         -- ETBN link information in a given direction
      etbnLineAstatus ANTIVALENT2,          -- Line A status (see 3)
      etbnLineBstatus ANTIVALENT2,          -- Line B status (see 3)
      etbnLineCstatus ANTIVALENT2,          -- Line C status (see 3)
      etbnLineDstatus ANTIVALENT2,          -- Line D status (see 3)
      etbnLineAdistIdent LINE-IDENT,        -- ETBN line distant Id. from Line A
      etbnLineBdistIdent LINE-IDENT,        -- ETBN line distant Id. from Line B
      etbnLineCdistIdent LINE-IDENT,        -- ETBN line distant Id. from Line C
      etbnLineDdistIdent LINE-IDENT         -- ETBN line distant Id. from Line D
                                                  --  (see 4)
}
```

```
ETB-TLV::= RECORD {              -- Definition of TTDP topology ETB specific TLV
      etbTlvHeader TLV-HEADER {        -- ETB TLV header values
            tlvType (1),
            tlvLength (0..511)
      },
      tlvCS            UNSIGNED16,           -- TLV checksum(see 7)
      protoID          TTDP-PROTO-ID,        -- TTDP protocol Id. string (see 1)
      protoVersion     UNSIGNED32 ('01000000'H), -- protocol version of the
                                                 --  ETB Inauguration Protocol (1.0.0.0)
      lifeSign         UNSIGNED32,           -- Sequence number of packet
                                             --  always incremented and overflow
      cstUuid          ARRAY [16] OF UNSIGNED8, -- Consist Universal Unique ID (see 2)
      etbnInaugState   ETBN-INAUG-STATE,     -- Status of the ETBN state machine
      etbnNodeRole     ETBN-ROLE,            -- Current role of the ETBN
      reserved1        UNSIGNED6 (0),        -- padding bits for 8-bit alignment
      etbnInhibition   ANTIVALENT2,          -- Informs about an inhibition request
                                        -- from this node. Local information from ETBN
                                             -- see HELLO frame note 6 for field coding
      reserved2        UNSIGNED6 (0),        -- padding bits for 8-bit alignment
      remoteInhibition ANTIVALENT2,          -- see 15 for role explanation
                                             -- and HELLO frame note 6 for field coding
      connTableCrc32   UNSIGNED32,           -- CRC32 of the internal Connectivity Table
                                             --  (see 5)
      etbnDir1LinkInfo ETBN-DIR-LINK-INFO,   -- ETBN link information in direction 1
      etbnDir2LinkInfo ETBN-DIR-LINK-INFO,   -- ETBN link information in direction 2
      dir1MacAddr      MAC-ADDR,             -- MAC address of the neighbour node
                                             --  in direction 1 (see 6)
      ownMacAddr       MAC-ADDR,             -- own MAC address
      dir2MacAddr      MAC-ADDR,             -- MAC address of the neighbour node
                                             --  in direction 2 (see 6)
      nDir1Etbn        UNSIGNED8 (0..62),    -- Number of ETBN detected at the dir1 side
                                             --  of the ETBN (see 14)
      nDir2Etbn        UNSIGNED8 (0..62),    -- Number of ETBN detected at the dir2 side
                                             --  of the ETBN (see 14)
      reserved3        UNSIGNED16 (0),       -- padding bytes for 32-bit alignment
      dir1EtbnVector   ARRAY [nDir1Etbn] OF MAC-ADDR,
                            -- Unordered ETBN list detected at the dir1 side,
                            --  each neighbour ETBN is described by its MAC address
      dir2EtbnVector   ARRAY ALIGN 32 [nDir2Etbn] OF MAC-ADDR
                            -- Unordered ETBN list detected at the dir2 side,
                            --  each neighbour ETBN is described by its MAC address
}

ETBN-CN-CNX::= BITSET32 {   -- Definition for CN connections bitmask
      -- for each bit, FALSE (0) means "not connected", TRUE (1) means "connected"
      cn01 (0),                  -- Consist network #1
      cn02 (1),                  -- Consist network #2
      -- ... to be filled with all intermediate values
      cn31 (30),                 -- Consist network #31
      cn32 (31)                  -- Consist network #32
}

CN-TYPE::= ENUM8 {
      cn-MVB                (1),
      cn-NotUsed            (2),
      cn-CAN                (3),
      cn-Ethernet           (4)
      -- Other values shall never be used
}
```

```
CN-TLV::= RECORD {              -- Definition of TTDP topology CN specific TLV
     cnTlvHeader TLV-HEADER {          -- CN TLV header values
          tlvType (2),
          tlvLength (0..511)
     },
     tlvCS            UNSIGNED16,           -- TLV checksum(see 7)
     etbTopoCnt       UNSIGNED32,           -- CRC32 of the internal
                                            --  "Train Network Directory" (see 13)
     ownEtbnNb        UNSIGNED8 (1..32),    -- Static relative position of the ETBN
                                            --  in the Consist (see 8)
     lengthen         ANTIVALENT2,          -- lengthening state (see 9)
     shorten          ANTIVALENT2,          -- shortening state (see 10)
     reserved1        UNSIGNED4 (0),        -- 4-bit padding for 8-bit alignment
     nEtbnCst         UNSIGNED8 (0..32),    -- Number of ETBN in the Consist (see 11)
     nCnCst           UNSIGNED8 (0..32),    -- Number of CN in the Consist (see 12)
     cnToEtbnList     ARRAY [nEtbnCst] OF ETBN-CN-CNX,
                                            -- List of CNs attached to ETBNs
     cnTypes          ARRAY ALIGN 32 [nCnCst] OF CN-TYPE
                                            -- Types of Consist networks
}

TTDP-TOPOLOGY-FRAME::= RECORD {  -- TTDP TOPOLOGY frame definition
     destAddr   MAC-ADDR ('0180C2000010'H),
                     -- Destination MAC multicast address (see IEEE 802.1D)
     srcAddr    MAC-ADDR,             -- Source MAC address (ETBN sender's)
     vlanHdr    TTDP-VLAN-HDR,        -- TTDP VLAN header
     etherType  UNSIGNED16 ('894C'H), -- EtherType id. for IEC TTDP topology protocol
     reserved1  UNSIGNED16 (0),       -- padding bytes for 32-bit alignment
     etbTlv     ETB-TLV,              -- ETB topology specific TLV (TTDP mandatory)
                -- Used to build "Connectivity Table" (Physical Topology)
     cnTlv      CN-TLV,               -- Consist Networks specific TLV (TTDP mandatory)
                -- Used to build "Train Network Directory" (Logical Topology)
     otherTlvs  SEQUENCE OF GEN-TLV,  -- optional list of TLVs
     eolTlv     EOL-TLV,         -- End Of TLV list (mandatory)
     etherCrc   UNSIGNED32       -- Ethernet frame CRC (see IEEE 802.3)
}
```

REMARKS

1) Plain text string (without zero termination). Used to filter Ethernet frames in monitoring tool.

2) All ETBNs inside the same Consist share the same CstUUID.

3) Line status of a line in a direction: could be used to monitor the ETB lines. Values are the following:

   ‘00’B (ERROR) = invalid value (shall never be used)

   ‘01’B (FALSE) = line Not OK

   ‘10’B (TRUE) = line OK

   ‘11’B (UNDEFINED) = not available.

4) Name of the neighbour connected line ('A', 'B', 'C' or 'D'). If neighbour name is unknown, ‘-‘ character shall be used.

   This could be used to monitor the ETB lines.

5) CRC32 calculated according to IEEE 802.3.

   Start value: ‘FFFFFFFF’H.

   Default value calculated on ConnTable with only one ETBN inside – this node (see 8.8.4).

6) Set to 0 if no neighbour node detected or if a previously detected neighbour node is not present any longer.

7) TLV checksum is calculated in the same way as HELLO TLV checksum. See 8.7.5.

8) Static relative position of the ETBN in the Consist: not to be confused with ETBN Id (the latter being dynamically computed at Inauguration time).

   Null value shall not be used.

9) Indicates a lengthening by an inaugurated composition (can be set by any node) i.e. appearance of new Consist. Detection by use of LLDP HELLO frame AND logical Topology.

   Set to TRUE if a node detects a new node with a CstUUID different from those contained in the Train Network Directory.

   Reset to FALSE (“stable”) by default and if Consists disappear OR new Train Network Directory (see 8.8.5).

Values are the following:

‘00’B (ERROR) = invalid value (shall never be used)

‘01’B (FALSE) = stable length

‘10’B (TRUE) = lengthening

‘11’B (UNDEFINED) = not available.

Initial value should be set to FALSE.

10) Indicates a shortening: loss of at least 1 Consist at end of train (can be set by any node). Detection by use of LLDP HELLO frame AND previous logical topology.

Set to TRUE if a node detects one or several Consists loss at train end according to Train Network Directory.

Reset to FALSE (“stable”) by default and if Consist appears again OR new Train Network Directory (see 8.8.5).

Values are the following:

‘00’B (ERROR) = invalid value (shall never be used)

‘01’B (FALSE) = stable length

‘10’B (TRUE) = shortening

‘11’B (UNDEFINED) = not available.

Initial value should be set to FALSE.

11) This information is part of the static description of a Consist.

ETBNs for the Consist are listed ordered in Consist direct orientation (ETBN#1 being the first one from Consist end 1).

12) This information is part of the static description of a Consist.

13) Calculated according to IEEE 802.3. Default value: see 8.7.5 for definition.

14) It is important to note that:

nDir1Etbn + nDir2Etbn ≤ (63-1)

even if independently each number is ≤ (63-1), as there are a maximum of 63 ETBN on the ETB (-1 to exclude own ETBN). Thus, the maximum data size of the ETB-TLV is:

70 + 62 * 6 = 442

which is less than the maximum data size for a TLV (511 bytes).

15) Indicates in the case of lengthening whether the remote composition is allowed to inaugurate (only set by end nodes). Initial value should be "UNDEFINED" which means it shall not be taken into account.

16) When connected to several ECNs and being master for at least one ECN, ETBN should be considered as EtbnRoleMaster (even if backup for another ECN).

The whole TTDP TOPOLOGY frame structure can be summarized by Figure 40 below:

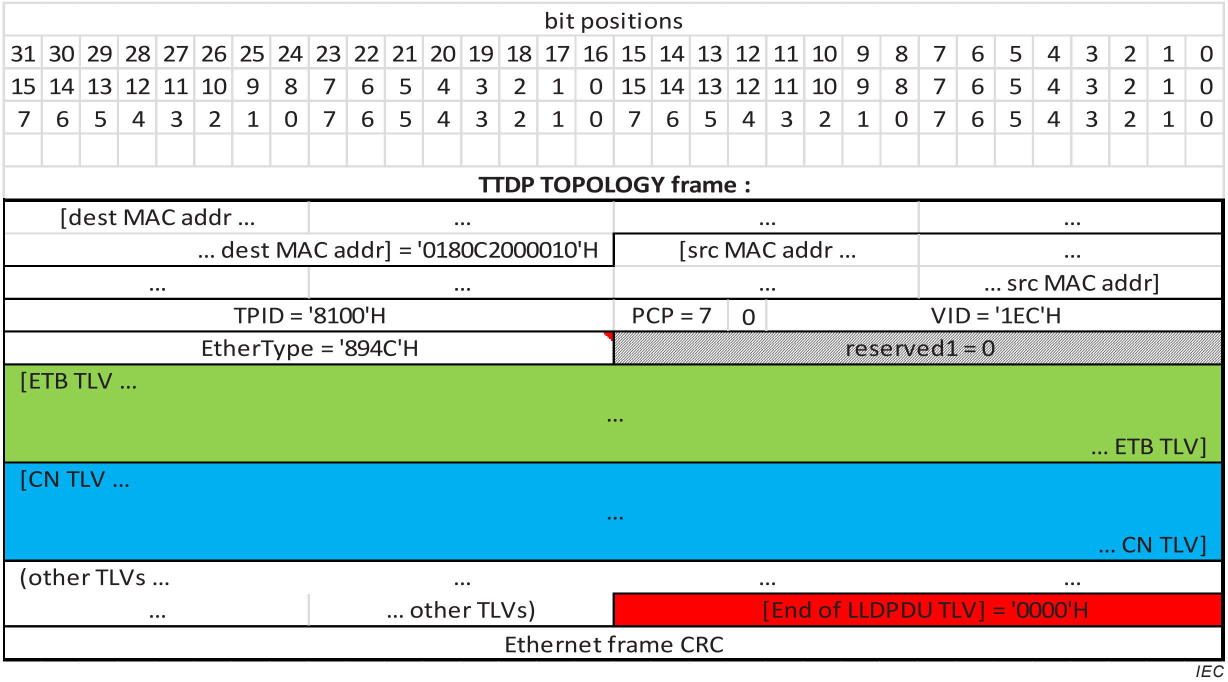


Figure 40 – TTDP TOPOLOGY frame structure

The TTDP TOPOLOGY specific TLV structures can be summarized by Figure 41 and Figure 42 below:

TTDP specific ETB TLV :			
TLV type (7 bits) = 1	TLV length (9 bits)	TVL checksum	
[proto ID ...	...	...	... proto ID] = "TTDP"
proto version = '01000000'H			
life sign			
[cst UUID ...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	... cst UUID]
ETBN inaug state	ETBN node role	reserved1 = 0 / e. inh.	reserved2 = 0 / r. inh.
conn. table CRC32			
lnA / lnB / lnC / lnD	dir 1 lnAdistIdent	dir 1 lnBdistIdent	dir 1 lnCdistIdent
dir 1 lnDdistIdent	lnA / lnB / lnC / lnD	dir 2 lnAdistIdent	dir 2 lnBdistIdent
dir 2 lnCdistIdent	dir 2 lnDdistIdent	[dir1 MAC addr ...	...
...	...	...	... dir1 MAC addr]
[own MAC addr ...	...	...	...
...	... own MAC addr]	[dir2 MAC addr ...	...
...	...	...	... dir2 MAC addr]
nb Dir1 ETBN (*n1*)	nb Dir2 ETBN (*n2*)	reserved3 = 0	
[dir1 ETBN#1 MAC addr ...	...	...	...
...	... dir1 ETBN#1 MAC addr]	[dir1 ETBN#2 MAC addr ...	...
...			
...			
...	...	[dir1 ETBN#*n1* MAC addr ...	...
...	...	...	... dir1 ETBN#*n1* MAC addr]
[dir2 ETBN#1 MAC addr ...	...	...	...
...	... dir2 ETBN#1 MAC addr]	[dir2 ETBN#2 MAC addr ...	...
...			
...			
[dir2 ETBN#n2 MAC addr ...	...		...
...	... dir2 ETBN#n2 MAC addr]	(0 padding for 32-bit alignment)	

: connectivity vector
: ETBN vectors

IEC

Figure 41 – TTDP TOPOLOGY specific ETB TLV structure

TTDP specific CN TLV :			
TLV type (7 bits) = 2	TLV length (9 bits)	TVL checksum	
etbTopoCnt			
own ETBN nb	length / shorte / reserved1 = 0	nb ETBN in consist (*n*)	nb CN in consist (p)
[cnToEtbnList#1			
...			
cnToEtbnList#*n*]			
[cnTypes#1	...	...	...
...	cnTypes#*p*]	(0 padding for 32-bit alignment)	

IEC

Figure 42 – TTDP TOPOLOGY specific CN TLV structure

8.8 TTDP data structures

8.8.1 Connectivity Vector

The Connectivity Vector (see Table 14 and Table 15) gives information about the direct neighbour nodes. The Connectivity Vector is a **part of TTDP TOPOLOGY frame** (see 8.7.6).

Each ETBN is able to build its own Connectivity Vector using TTDP HELLO or TTDP TOPOLOGY frames.

Definition:

Table 14 – Connectivity Vector

	b47..b0
0	MAC address (DIR 1)
1	MAC address (OWN)
2	MAC address (DIR 2)

With:

Table 15 – Connectivity Vector Fields

Entry	Description	Value
MAC Address	MAC address of the neighbour node in directions 1 and 2 or own MAC address. Set to 0 if no neighbour node detected or if a previously detected neighbour node is not any longer present	‘XXXXXXXXXXXX’H

8.8.2 ETBN Vector

The ETBN Vector (see Table 16 and Table 17) gives information about all neighbour nodes detected from a specific direction (DIR1 or DIR2). List of detected ETBNs is not ordered. Two ETBN Vectors are **included in TTDP TOPOLOGY frame** (see 8.7.6). Each ETBN is able to build these two ETBN Vectors (in both directions) using multicast TTDP TOPOLOGY frames (one reception from each other ETBN is enough). When receiving a TTDP TOPOLOGY frame, a simple lookup inside ETBN switch forwarding table gives the incoming port number, so direction of the sender shall be easily deduced by ETBN.

Definition:

Table 16 – ETBN Vector

	b47..b0
0	MAC address
…	MAC address
N	MAC address

With:

Table 17 – ETBN Vector Fields

Entry	Description	Value
MAC address	MAC address of a neighbour node from a specific direction.	‘XXXXXXXXXXXX’H

8.8.3 Connectivity Table

The connectivity table (see Table 18 and Table 19) contains the list of physical ETBNs detected on the backbone: “physical topology”. This list is computed from the TOPOLOGY frames. The first entry belongs to the train ending ETBN with the lowest Consist UUID (CstUUID in TTDP TOPOLOGY frame). The ETB reference direction is used as orientation reference and ETBN orientation is calculated according to train reference direction. The connectivity table is recomputed by all ETBN each time they receive a new TOPOLOGY frame.

For any ETBN just after initialisation time, minimal Connectivity Table (default value) contains only one node, itself.

Table 18 – Connectivity Table

<table>
<tr><th></th><th>b7..b6</th><th>b5..b0</th></tr>
<tr><td rowspan="8">ETB Top Node first

(defined by the lowest CstUUID value between ending node values)</td><td>Orientation</td><td>0</td></tr>
<tr><td colspan="2">0</td></tr>
<tr><td colspan="2">MAC address(OUI)</td></tr>
<tr><td colspan="2">MAC address(OUI)</td></tr>
<tr><td colspan="2">MAC address(OUI)</td></tr>
<tr><td colspan="2">MAC address(specific)</td></tr>
<tr><td colspan="2">MAC address(specific)</td></tr>
<tr><td colspan="2">MAC address(specific)</td></tr>
<tr><td>...Intemediate ETBN ...</td><td>...</td><td>....</td></tr>
<tr><td rowspan="8">ETB Bottom Node last</td><td>Orientation</td><td>0</td></tr>
<tr><td colspan="2">0</td></tr>
<tr><td colspan="2">MAC address(OUI)</td></tr>
<tr><td colspan="2">MAC address(OUI)</td></tr>
<tr><td colspan="2">MAC address(OUI)</td></tr>
<tr><td colspan="2">MAC address(specific)</td></tr>
<tr><td colspan="2">MAC address(specific)</td></tr>
<tr><td colspan="2">MAC address(specific)</td></tr>
</table>

With:

Table 19 – Connectivity Table fields

Entry	Description	Type	Value
MAC Address	MAC address of all detected ETBNs on ETB	uint8[6]	‘XXXXXXXXXXXX’H
Orientation	Information about the orientation of the node with respect to ETB reference direction	Antivalent2-bit field	‘00’B -> error ‘01’B -> direct (same orientation as ETB reference direction) ‘10’B -> inverse ‘11’B -> undefined

8.8.4 Connectivity Table CRC

Connectivity Table CRC32 checksum is called ConnTableCrc32. It is computed according to IEEE 802.3, this is a 32-bit unsigned integer, with a default value corresponding to the CRC of the Connectivity Table limited to only one ETBN: the own ETBN . Connectivity Table CRC is transmitted in TTDP TOPOLOGY frame (see 8.7.6).

Connectivity table CRC32 is computed from the byte of ETB Top Node containing Orientation to the byte of ETB Bottom Node containing Mac address specific last byte. Connectivity Table CRC is transmitted in TTDP TOPOLOGY frame (see 8.7.6).

When all ETBNs send the same value, all ETBNs share the same Connectivity Table. In other words, all ETBNs know all the others: Physical Topology is complete.

8.8.5 Train network directory

The Train Network Directory (see Table 20 and Table 21) contains the train description in terms of CN: “Logical Topology”. The first entry belongs to the train ending CN with the lowest CstUUID. This Consist is used as train orientation reference. The Train Network Directory (TNDir) is recomputed by all ETBNs each time they receive a new TTDP TOPOLOGY frame (see 8.7.6).

Table 20 – Train network directory

	uint8[16]	uint32							
		b31..b30	b29..b24	b23..b22	b21..b16	b15..b14	b13..b8	b7..b2	b1..b0
0	CstUUID (the lowest CstUUID value among ending Consist values)	0	CN Id = 1 (more than one CN could be defined inside the Consist)	0	Subnet Id	0	ETBN Id	0	CstOrientation
1	CstUUID	0	CN Id	0	Subnet Id	0	ETBN Id	0	CstOrientation
…	…/…								
n	CstUUID	0	CN Id	0	Subnet Id	0	ETBN Id	0	CstOrientation

With:

Table 21 – Train network directory fields

Entry	Description	Type	Value
CstUUID	Consist Universal Unique ID (IETF RFC 4122).	uint8[16]	Example: ‘f81d4fae-7dec-11d0-a765-00a0c91e6bf6’H
CN Id	As the previous field, statically defined, it identifies the CN inside the Consist.	6-bit field (bit5..bit0)	1..32
Subnet Id	Used to number the CN subnet on ETB.	6-bit field (bit5..bit0)	1..63
ETBN Id	Used to number the ETBN on ETB.	6-bit field (bit5..bit0)	1..63
CstOrientation	Orientation of the Consist in relation of train reference direction.	Antivalent2-bit field (bit1..bit0)	‘00’B -> error ‘01’B -> direct ‘10’B -> inverse ‘11’B -> undefined

Train Network Directory entries shall be ordered by "serializing" lists of Consists, CN Ids and ETBN Ids as follows:

– First level ("Consists serialization"): as specified above, the first Consist in TNDir is the one with the lowest CstUUID among end Consists. Then the second Consist in TNDir (if any) is the next Consist in ETB reference direction 2 (i.e. direction of ETBN ascending order). And so on to the last Consist (see 8.2.1).

– Second level ("CN Ids serialization"): there is one record (one entry in TNDir array) for each CN in each Consist. For each Consist, CN Ids are in ascending order if the Consist has direct orientation. Else, if the Consist has inverse orientation, CN Ids are in descending order.

– Third level ("ETBN serialization"): there is one record (one entry in TNDir array) for each ETBN in each CN. ETBN Ids are in ascending order.

NOTE

– CN Ids are known from static Consist configuration data. ETBNs are also described in these data and listed in Consist orientation order.

– Subnet Ids are directly associated with CN Ids (as soon as physical topology is known).

– ETBN Ids for a given CN in TNDir also include missing nodes (if any), i.e. all ETBN Ids for a given CN as listed in corrected physical topology (all ETBNs known by static configuration data, see 8.8.7).

An example is given below for the train composition on Figure 43:

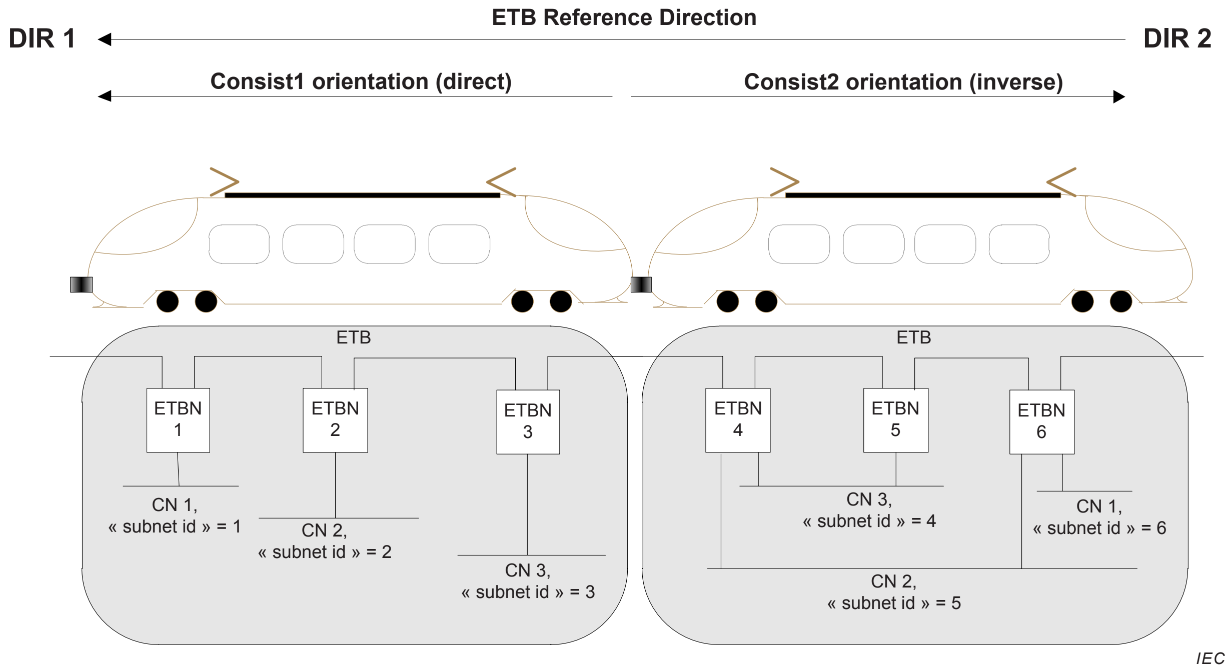


Figure 43 – Train composition for TNDir example

Its Train Network Directory is organized as presented in Table 22 below (the first column being the line index which is not part of the TNDir):

Table 22 – Train network directory (example)

	uint8[16]	uint32							
	CstUUID	b31..b30	**CN Id**	b23..b22	**Subnet Id**	b15..b14	**ETBN Id**	b7..b2	**CstOrientation**
0	**Consist1 CstUUID**	0	**1**	0	**1**	0	**1**	0	**'01'B**
1	**Consist1 CstUUID**	0	**2**	0	**2**	0	**2**	0	**'01'B**
2	**Consist1 CstUUID**	0	**3**	0	**3**	0	**3**	0	**'01'B**
3	**Consist2 CstUUID**	0	**3**	0	**4**	0	**4**	0	**'10'B**
4	**Consist2 CstUUID**	0	**3**	0	**4**	0	**5**	0	**'10'B**
5	**Consist2 CstUUID**	0	**2**	0	**5**	0	**4**	0	**'10'B**
6	**Consist2 CstUUID**	0	**2**	0	**5**	0	**6**	0	**'10'B**
7	**Consist2 CstUUID**	0	**1**	0	**6**	0	**6**	0	**'10'B**

8.8.6 Train network directory CRC (Topology Counter)

Train network directory CRC32 is a 32-bit unsigned integer and called etbTopoCnt. It is computed according to IEEE 802.3, with a default value corresponding to the CRC32 of the train network directory limited to only one Consist: the own ETBN Consist.

Train network directory CRC is transmitted in TTDP TOPOLOGY frame. When all ETBNs send the same value, all ETBNs share the same Train Network Directory. In other words, all ETBNs know all the train CN description. ETBNs share the same “subnet Ids” and “ETBN ids”, they are able to launch Inauguration.

As stable Train network directory CRC identifies a Train IP configuration, this value is also named and used as “Topology Counter” (to be compared with "topography counter" TopoCount concept in IEC 61375-1, 5.6.2).

If Train Inauguration is not allowed, the TTDP TOPOLOGY frame shall contain the last valid stable value of etbTopoCnt (last value set by SetEtbTopoCnt function, see 8.5.2). If Train Inauguration is allowed, the TTDP TOPOLOGY frame shall contain the CRC32 of the current Train Network Directory (last value calculated by BuildLogicalTopology function, see 8.5.2).

8.8.7 Corrected topology

Internally, each ETBN should maintain a "corrected physical topology" derived from actual physical topology. It contains all the ETBNs discovered (from received TOPOLOGY frames) and stored in connectivity table (physical topology), plus inserted missing ETBNs (if any).

Missing ETBNs can be guessed from static Consist description advertised in CN TLV in TTDP TOPOLOGY frames (see 8.7.6). They are inserted at their expected positions on the ETB according to Consist orientation and ETBN ordered list in Consist static description. Thereby, ETBN Ids and IP addresses can be assigned at Inauguration time without being disturbed by late nodes: late nodes have reserved IDs and IP addresses,

NOTE

- Missing ETBNs do not provide MAC addresses until they appear on ETB.
- Corrected physical topology is an internal data structure and this information is not advertised as such in TTDP TOPOLOGY frames.

As defined in 8.8.5, logical topology is already a "corrected" topology. It contains all ETBNs and subnets (CN), even missing ones. It is actually built from corrected physical topology and static Consist description.

8.9 TTDP frames timing

8.9.1 TTDP HELLO

TTDP HELLO frames shall be sent unconditionally by all ETBNs over all ETB switch ports, independently of link aggregation (i.e. on each physical line configured for being used).

TTDP Hello timing algorithm is like LACP (Link Aggregation Control Protocol) or MRP (ring). Two sending periods are defined for TTDP HELLO:

- a slow sending period in normal mode, to reduce CPU and network loads, associated with a long reception timeout. "Slow period" shall be set to 100 ms.
- a shorter sending period in fast mode, to improve line error detection performance, associated with a short reception timeout. "Fast period" shall be set to 15 ms. In this mode ETBN peer shall modify its own mode and answer to each received TTDP HELLO frame.

Illustration with periods values and suggested timeouts to reach the recovery time requirement:

- SlowPeriod 100 ms
- SlowTimeout 1,3 × SlowPeriod = 130 ms
- FastPeriod 15 ms
- FastTimeout 3 × FastPeriod = 45 ms

Detection time = SlowTimeout + FastTimeout = 175 ms

Recovery time (Detection time + Link aggregation reconfiguration time) shall be less than 200 ms. Figure 44 and Figure 45 below show TTDP HELLO protocol timing (UML sequence diagrams):

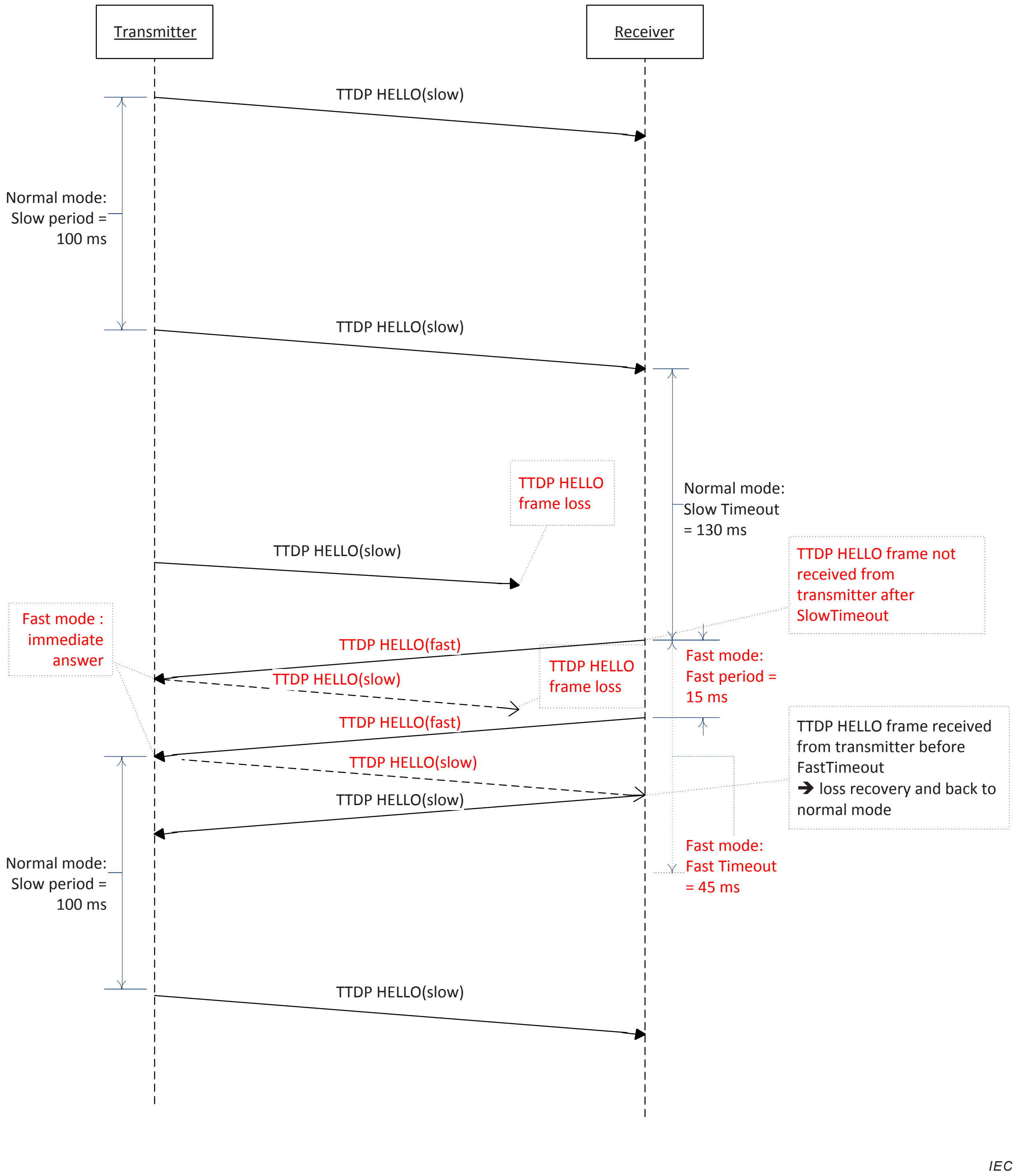


Figure 44 – TTDP HELLO normal mode and recovery timing

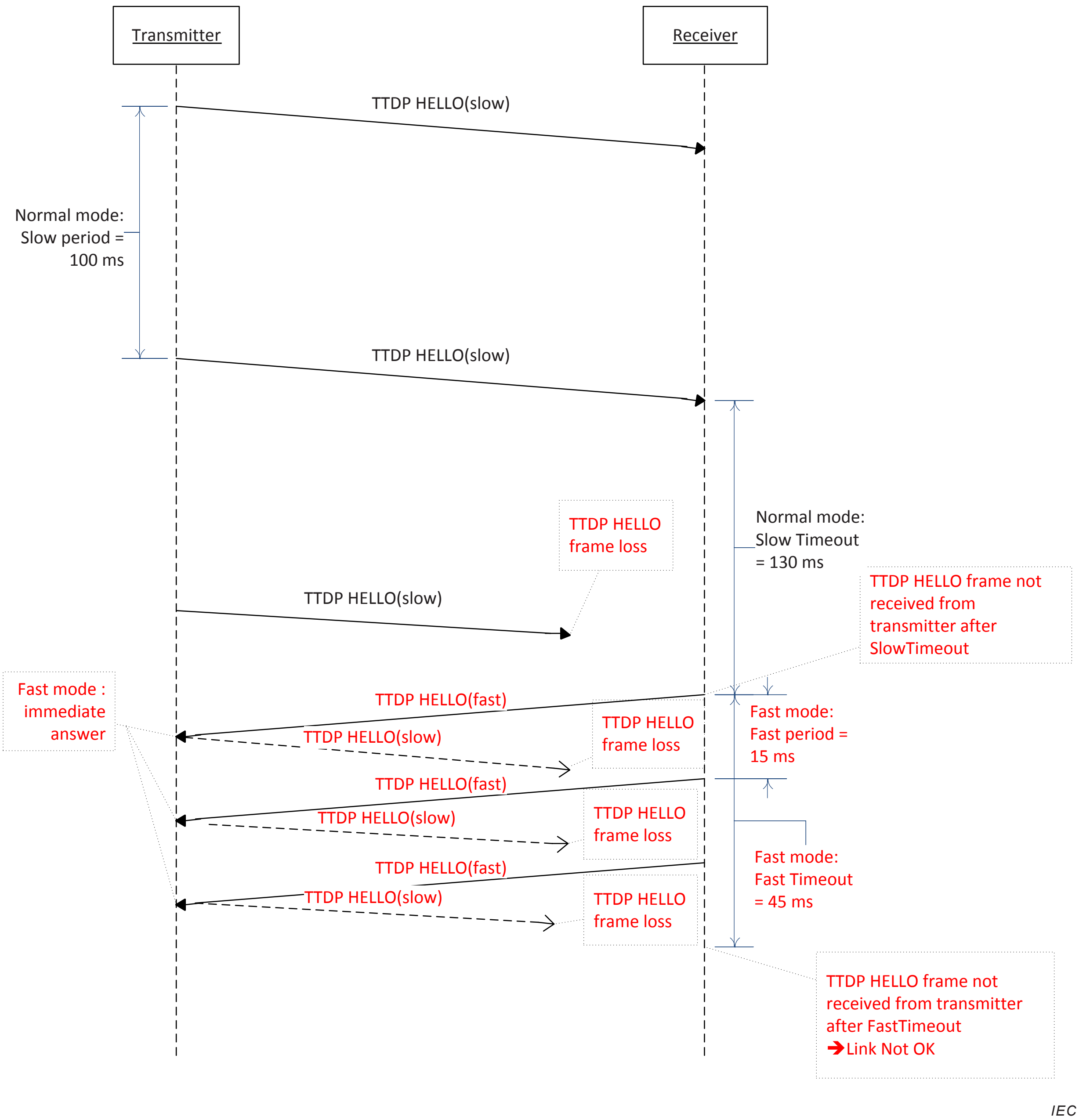


Figure 45 – TTDP HELLO failure timing

Notes about the illustrations above, for sake of simplicity:

- Only one direction of the HELLO protocol is described in these figures, but it must be kept in mind that it is managed in both directions (i.e. the Receiver on the left is also a TTDP HELLO frames Transmitter when checking the other direction and the Transmitter is then the Receiver).
- The presented use cases illustrate communication problems in only one direction (from Transmitter to Receiver), the Transmitter always correctly receiving frames from the Receiver.

8.9.2 TTDP TOPOLOGY

TTDP TOPOLOGY frames shall be sent unconditionally by all ETBNs over ETB using link aggregation groups.

Sending period of TTDP TOPOLOGY shall be set to 100 ms.

Received TTDP TOPOLOGY information shall have a validity duration of 400 ms maximum. As no explicit TTL value is provided in the TTDP TOPOLOGY frame, a local timeout of 400 ms shall be handled on each ETBN for each received TTDP TOPOLOGY information. When the timeout has elapsed without receiving a new TTDP TOPOLOGY frame from a previously known ETBN, the corresponding TOPOLOGY information becomes invalid and the remote ETBN shall be considered as missing.

Each ETBN shall also handle a global TTDP TOPOLOGY frames receive timeout: its value is 1 s. When it has elapsed (i.e. no TTDP TOPOLOGY frame received from any node), the node can consider it is alone on the ETB and topology is stable.

Figure 46 below (UML activity diagram) illustrates TTDP TOPOLOGY frames handling:

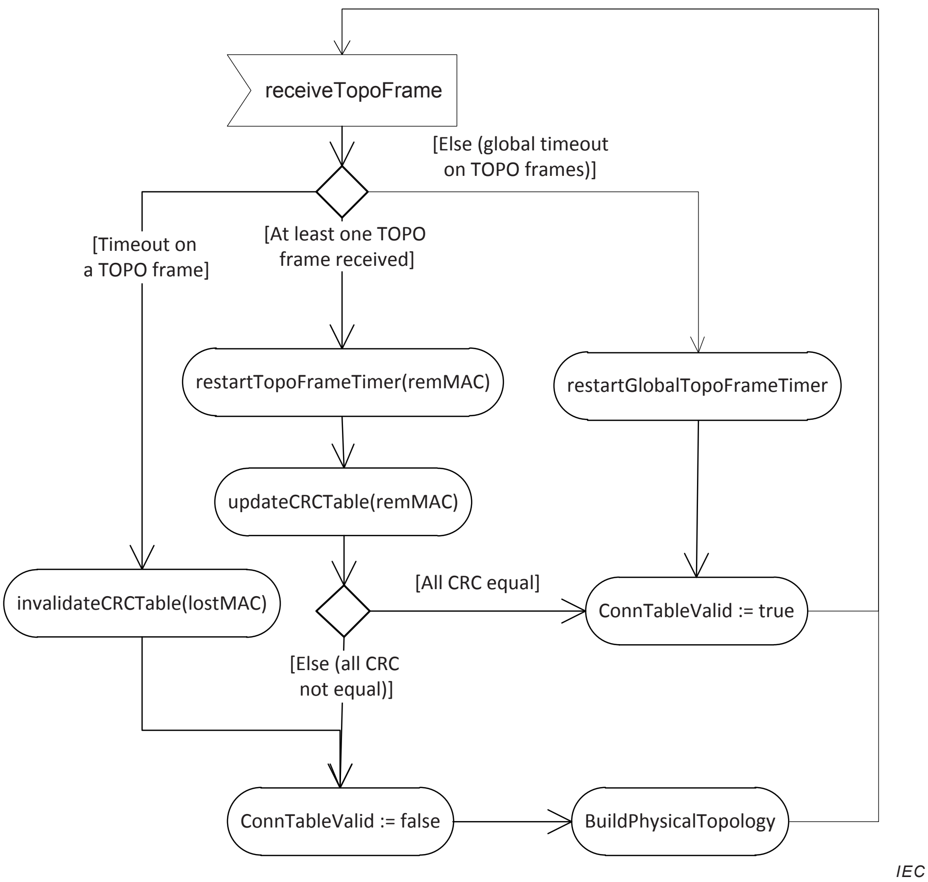


Figure 46 – TTDP TOPOLOGY frames handling

For data description, see Annex B.

Conditions:

– **At least one TOPO frame received**: at least one TTDP TOPOLOGY frame was received before global timeout. This means the local ETBN is not alone on the ETB.

– **Else (global timeout on TOPO frames)**: global timeout expired when waiting for incoming TTDP TOPOLOGY frames. This means the local ETBN is alone on ETB. Physical topology can be considered as stable, consisting in only own ETBN on ETB.

– **Timeout on a TOPO frame**: a previously received ETBN TOPOLOGY frame timeout has elapsed, which means the corresponding ETBN has disappeared from ETB.
– **All CRC equal**: all connectivity tables CRC are equal. This means that the same physical topology is shared between all ETBNs.
– **Else (all CRC not equal)**: all connectivity tables CRC are not equal.

Actions:

– **receiveTopoFrame**: wait for incoming TTDP TOPOLOGY frames.
– **restartGlobalTopoFrameTimer**: restart global TOPOLOGY frames timer with its timeout value (1 s).
– **restartTopoFrameTimer(remMAC)**: restart TOPOLOGY frame timer for the remote ETBN with its timeout value (400 ms).
– **updateCRCTable(remMAC)**: update received CRC for the remote ETBN in CRCTable with the new received connectivity table CRC in TTDP TOPOLOGY frame.
– **invalidateCRCTable(lostMAC)**: invalidate the locally stored connectivity table CRC for the remote ETBN in CRCTable (the one with lostMAC address whose timeout has elapsed).
– **BuildPhysicalTopology**: run physical topology building algorithm (see details in Annex B) and update connectivity table according to received TTDP TOPOLOGY frame information.
– **ConnTableValid:= True**: set status of local connectivity table to stable.
– **ConnTableValid:= False**: set status of local connectivity table to unstable.

8.10 Inauguration Train Application interface

An interface shall be defined between ETBN and CN devices where train application runs. As multiple types of CN exist: Ethernet (ECN), MVB, CAN,etc., definition of this interface is let free or defined inside CN document.

Minimum interactions shall be:

– Advertise train application from ETBN when Inauguration status changes,
– Get Inauguration status from application,
– Get train topology from application,
– Set or Clear Inauguration inhibition flag from train application.

8.11 Degraded modes

8.11.1 Late insertion ETBN

Late insertion of an ETBN shall be detected using TTDP TOPOLOGY frame (as CN description is exchanged between Consists): late nodes start with their ports in forwarding mode state, meaning communication between already inaugurated nodes is not disturbed.

– First case: the late ETBN belongs to a Consist already identified in the logical topology.

  The topology discovery algorithm requires only one ETBN by Consist to calculate the actual train topology. Each ETBN has a complete description of Consist architecture which comprises ETBN number, Consist network number, attachment between ETBN and Consist Network. When alive, ETBNs share the same Train Network Directory, they are able to reserve some numbers for missing nodes and Inauguration shall be done without waiting for these late nodes. New Inauguration is avoided when the late nodes wakeup (a number is reserved for them): late nodes converge to the same logical topology (the same etbTopoCnt as others nodes) and can pass in state INAUGURATED.

– Second case: the late ETBN belongs to a Consist not already identified in the logical topology.

New Inauguration shall not be avoided for late power of a Consist. The late ETBN cannot converge to a logical topology as other nodes have another etbTopoCnt in their TOPOLOGY frame. A new Inauguration can happen if InaugInhibition equals to False (all already inaugurated nodes decide it).

8.11.2 Losing ETBN

Losing an ETBN shall not imply a new Inauguration.

Losing a non-redundant ETBN stops ETB communication for the concerned CN. Other CN are not affected (even in the same Consist).

Losing a “backup” (redundant) ETBN has no effect.

Losing a “master” (redundant) ETBN interrupts CN-ETB communication for the time that the “backup” ETBN becomes the new “master” ETBN of this CN.

In all cases, new Inauguration shall not be performed when losing an ETBN. Updated information in TTDP TOPOLOGY frames shall allow correcting connectivity table and inform train application of the ETBN loss. See "corrected physical topology" in 8.8.7.

The particular case for an intermediate ETBN loss when the ETBN is the only node of a Consist is handled by InaugInhibition mechanism in order to prevent from a new inauguration.

8.11.3 End ETBN failure and partial topology counter

An uncoupling or a failure of end node(s) are seen as a loss of end node(s).

Uncoupling is detected by the loss of at least one end Consist: the Train Network Directory (logical topology) changes which entails a new Inauguration if allowed. If Inauguration is not allowed, the topology remains the same as the last stable one with an unreachable Consist.

If an end Consist contains several nodes and only the end node fails, the Train Network directory is unmodified: no new Inauguration happens.

In order to enhance availability in case of end node temporary failure, the TTDP algorithm may authorize recovery of end node(s) and associated Consist network even if Inauguration is not allowed (in state INAUGURATED).

When an end node fails, Discarding port moves to its neighbour node. The main issue for recovering the lost end node after its temporary failure is to unlock ports of its neighbour. By comparing the etbTopoCnt sent by the recovered end node (in TTDP HELLO frame) to partial topology counters of current logical topology, the neighbour node can unlock its ports.

Partial topology counters are computed by the current end node when it receives a new HELLO frame through its end link (ports in Discarding state). It then tries to match received etbTopoCnt in HELLO frame from its new neighbour with computed partial topology counters: partial topology counters are computed on limited parts of the current Train Network Directory containing the new appearing node. When a match is obtained, the current end node can set its Discarding ports in Forwarding state since its new neighbour shares the same partial topology. This ensures that no new unknown nodes are introduced without a new Inauguration.

8.12 Some discovery timing

8.12.1 ETBN wakeup

Figure 47 shows wakeup of a train with 3 ETBNs:

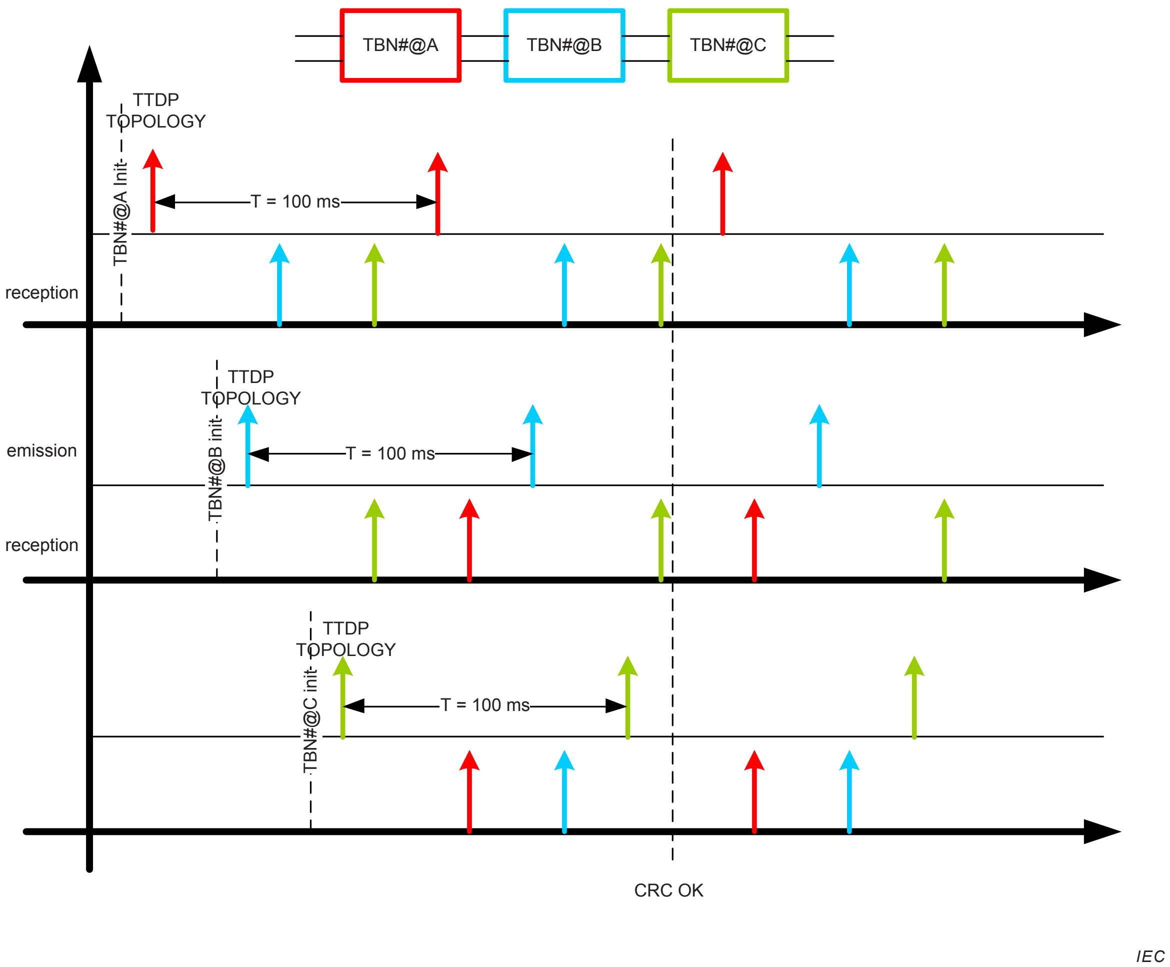


Figure 47 – TTDP ETBNs wake up timing

It should be considered that discovery timing depends on the last wakeup ETBN in the last wakeup Consist and not on the total number of ETBNs.

8.12.2 ETBN failure

Figure 48 shows ETBN failure detection by discovery process:

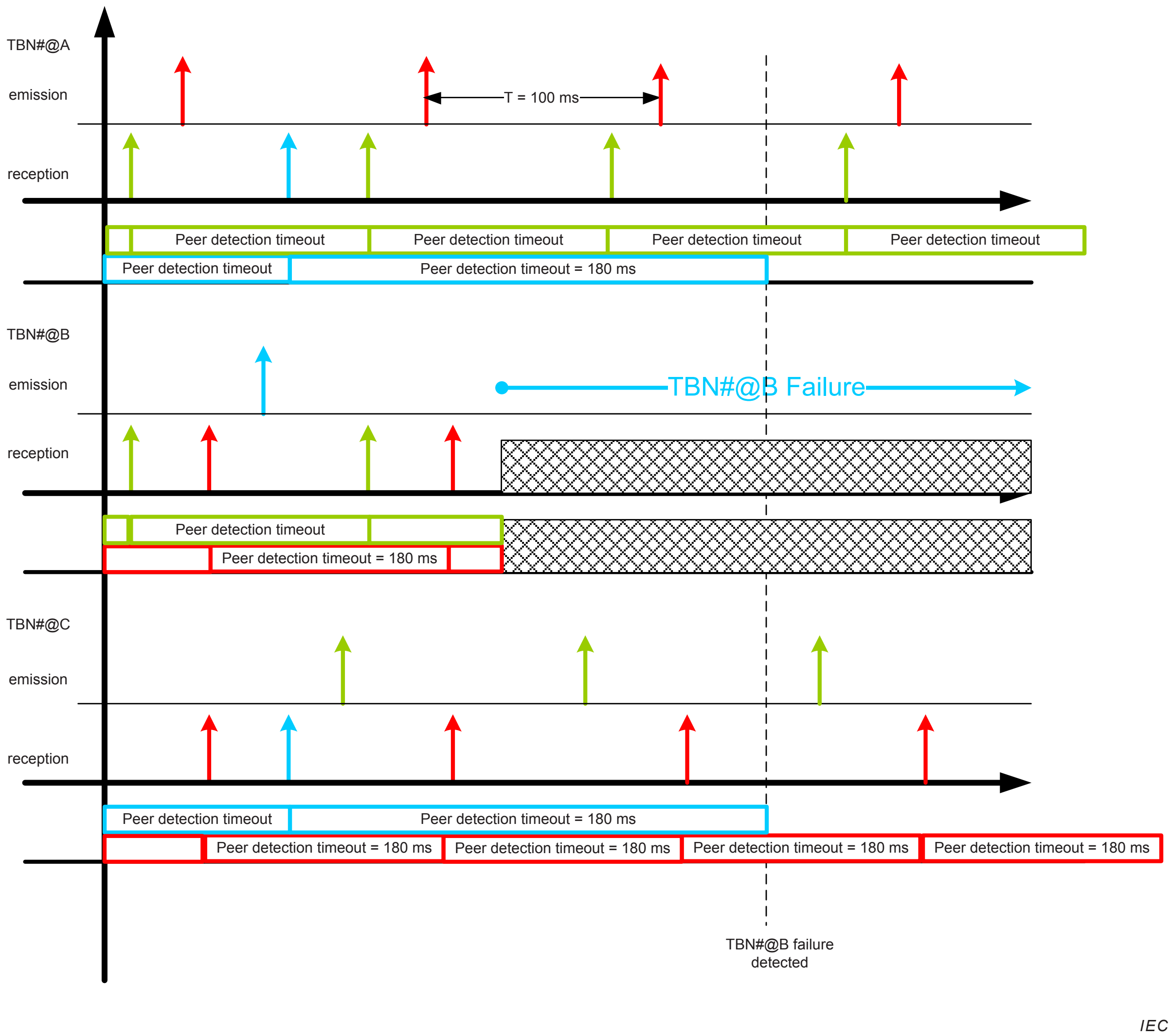


Figure 48 – TTDP ETBN failure timing

Train application is advertised of ETBN failure but new Inauguration shall be avoided due to Inauguration inhibition application flag. ETBN numbering and IP address mapping do not change.

8.12.3 Consist coupling

Figure 49 shows TTDP HELLO message detection timing:

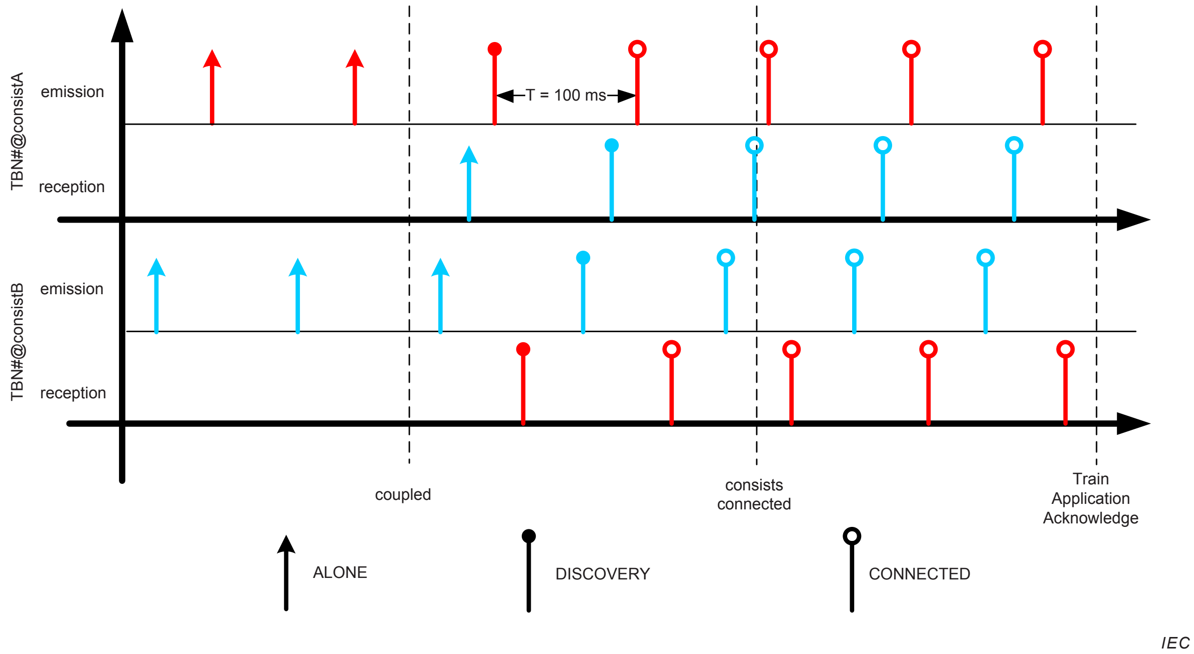


Figure 49 – TTDP Consist coupling timing

After acknowledgement by train application of coupling, extremity ports are opened and TTDP TOPOLOGY messages are multicast.

9 ETB ETBN redundancy

Each CN subnet shall be accessed from ETB, using a unique IP route. This is a mandatory requirement for ETB interoperability issue.

For a specific CN without ETBN redundancy, this IP route is set to ETB interface of its unique ETBN (see Figure 50). As reminder, ETBN train IP address is dynamically defined after Inauguration, see 6.5.1.2 for definition. This unique ETBN train IP address is used by all other train ETBNs as target IP route for this CN.

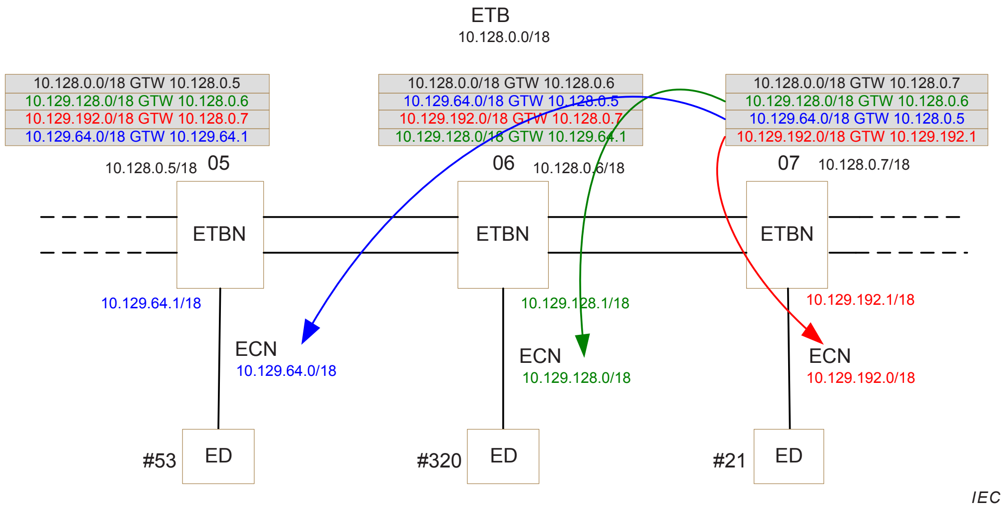


Figure 50 – Example of ETBN IP routing table without redundancy

In case of multiple ETBNs for a same CN, this train IP address shall be shared between all redundant ETBNs as a virtual IP address (without virtual MAC address, see Figure 51). At any time, only one redundant ETBN exports this IP address, this ETBN is the redundancy master, the others are called backup ETBN. Virtual train IP address for redundant ETBN is defined in 6.5.1.2.

ETBN Master/Backup mode shall be managed by exchanges at CN level, see CN network descriptions for more details (IEC 61375-3-4 for Ethernet ECN).

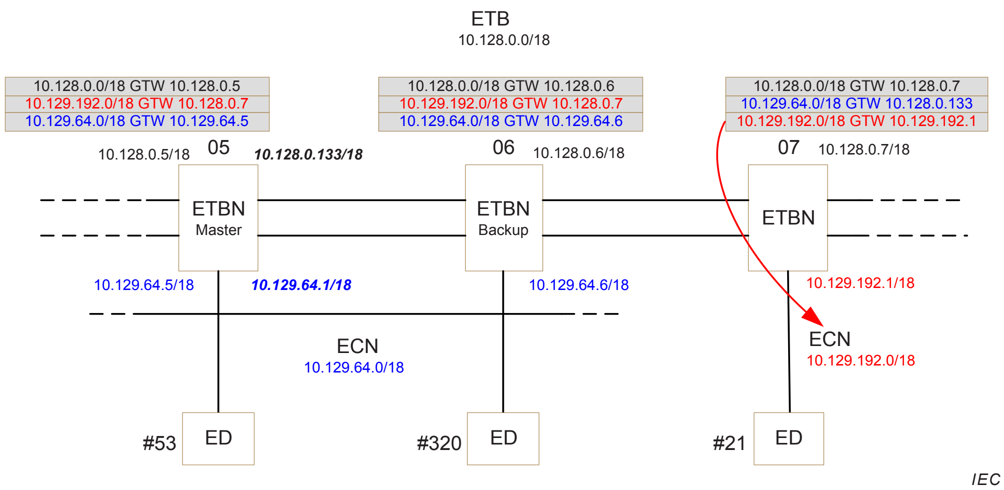


Figure 51 – Example of ETBN IP routing table with redundancy

Each ETBN is directly connected on ETB at level 2 layer. All ETBNs are able to communicate directly with any ETBN.

ETBN master election is not described in this standard because the election is not relevant to interoperability.

ETBN redundancy status shall be periodically made available to application using a status flag (“is_master” flag for example).

ETBN redundancy status should be available for monitoring using SNMP.

10 ETB physical train naming convention (optional)

10.1 General

In a specific train, each host with a train IP address (End Device or Network Device) shall be identified by an unambiguous train Full Qualified Domain Name (FQDN).

This requirement is solved by an optional train domain definition implementation.

As reminder a FQDN, “hostname.domain.tld.”, is composed of two parts:

- “hostname”: device physical identification. It shall be unique inside a domain.
- ”domain.tld.”: domain identification, “tld” is the top level domain and “domain” could be split in a hierarchy of sub-domains.

The following subclauses describe domain implementation and simple rules to hostname part definition.

10.2 ETB Train domain

ETB Train domain is used to identify each physical ED inside the train. All EDs shall have a FQDN inside this domain: Train FQDN. It defines an unambiguous physical ED identification without any other signification.

Train FQDN definition shall be available inside all the train. Train FQDN shall always be translated to train IP address.

Standard Domain Name System (DNS) protocol (IETF RFC 1035) shall be available on ETB between Consists (inter-Consist interface) to convert Train FQDN into train IP address.

ETB Train domain shall be defined using Train Network Directory contents. So ETB Train domain is valid for a given Topology Counter.

ETB Train domain shall be defined as on Figure 52:

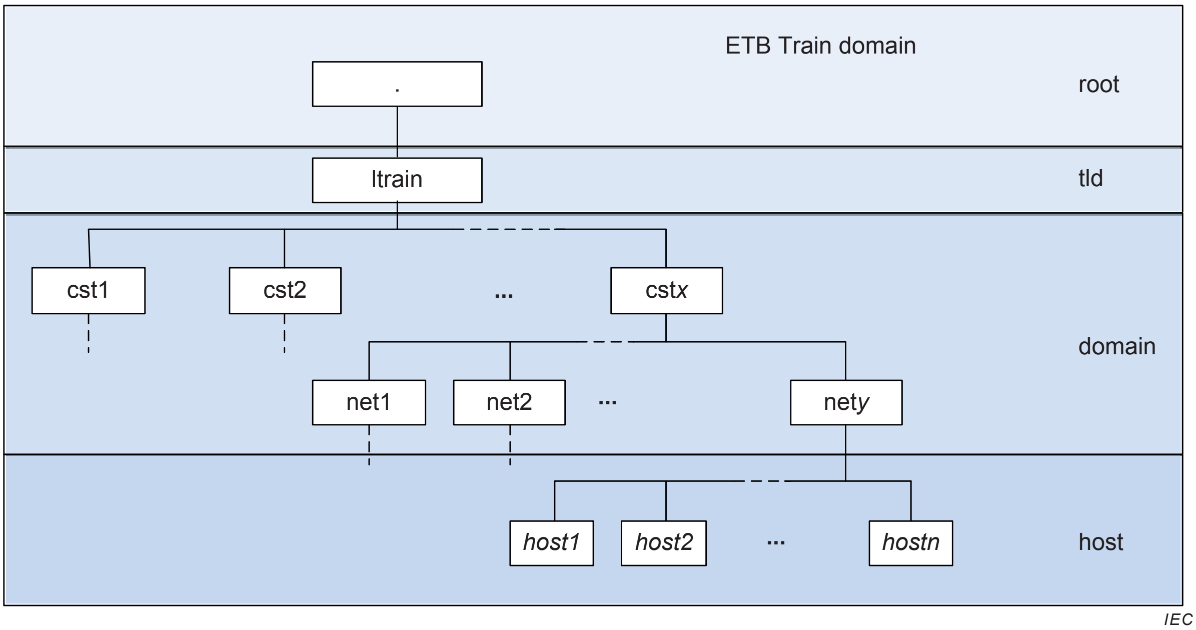


Figure 52 – ETB train domain defintion

ETB tld shall be “ltrain“.

ETB domain shall be “net***x***.cst***y***”, where “***x”*** is the CN Id (see Train Network Directory) and “***y”*** is the train Consist number, dynamically determined during Inauguration (be careful to not confuse ***y*** with “Subnet Id”).

As a consequence: inside a given CN, hostnames shall be unique.

NOTE

– As can be seen above on Figure 52, hosts may have more than one FQDN, in several domains, defined at different levels: ETB, ECN, etc. or for different purposes: maintenance, functional, ground communication, etc.

– This domain name structure is informal. IEC 61375-2-3 and future IEC 61375-2-4 are the specifications for functional addressing.

10.3 Hostname

End device train FQDN hostname part shall be defined by project in accordance with IETF RFC 1035.

End device hostname shall be unique inside ETB train domain (see above).

End device name should be user friendly (see IETF RFC 1178).

For example:

- Use type name or acronym: DDU for driver display unit, MPU for main processing unit,etc.
- Optionally completed by an instance number (1, 2,etc.)

Example: mpu, DDU1, ddu2, etc.

End device name is case insensitive (IETF RFC 1033): mpu, MPU,etc., are equivalent names.

11 ETB Quality of Service

11.1 Contents of this clause

This clause specifies the quality characteristics of the services provided by the ETB. These quality characteristics shall ensure that a service can fulfil its requirements under all operational conditions of the ETB.

11.2 Frame forwarding

11.2.1 ETBN switching rate

Ethernet frame forwarding between input and output of ETB ports shall be performed at full wire speed.

11.2.2 No Head-of-Line blocking

An output port that is congested or slow shall never affect the transmission of frames to un-congested ports.

11.2.3 Switching priorities

ETBNs shall support at least 4 different priorities for Ethernet frames switching.

The priority of a frame shall be defined by its IP TOS/Differentiated Services field following the recommendations given in IETF RFC 2474.

The mapping of the differentiated codepoints (DSCP as defined in RFC 2474) to the four priorities shall be as defined in Table 23:

Table 23 – DSCP field mapping

DSCP field	Priority
‘11X000’B	Highest
‘10X000’B	2nd highest
‘01X000’B	3rd highest
‘00X000’B	Lowest (Default)

with “X” being “0” or “1”.

If not otherwise defined, the priority of a frame shall be defined by its VLAN priority field following the recommendations given in IEEE 802.1Q (see Table 24).

Table 24 – ETB Switching Priorities

IEEE recommendations			Minimum ETB priority mandatory management (4 levels)		IEC 61375-2-5 conformance
Priority	VLAN priority bit field	Traffic Type	VLAN priority bit field	Switching priority	M Mandatory, R Recommended
0	‘000’B	Best Effort	‘00x’B	Lowest (default)	M
1	‘001’B	Background			
2	‘010’B	Spare	‘01x’B	3rd highest	M
3	‘011’B	Excellent Effort			
4	‘100’B	Controlled Load	‘10x’B	2nd highest	M
5	‘101’B	Video			
6	‘110’B	Voice	‘11x’B	Highest	M
7	‘111’B	Network Control			

11.2.4 Switching queuing scheme

Switching shall be performed with strict priority queuing.

NOTE With strict priority queuing, all higher priority frames egress an ETBN port before the lower priority frames egress.

11.3 Priority of Inauguration frames

Inauguration frames (TTDP HELLO and TOPOLOGY frames) shall be sent with the highest IEEE 802.1Q frame priority: 7.

11.4 ETB ingress rate limiting

The ETBN may provide the possibility to limit the rate of frames ingress from the Consist Network or from a directly connected ED.

If frames need to be discarded to keep the rate limit, low priority frames shall be discarded first.

NOTE Ingress rate limiting prevents an ETB from being unintentionally flooded with frames originating from one faulty Consist Network or one directly connected faulty ED.

11.5 ETB egress rate shaping

The ETBN may provide the possibility to limit the rate of frames egressing to the Consist Network or to a directly connected ED.

If frames need to be discarded to keep the rate limit, low priority frames shall be discarded first.

11.6 ETB data classes

IEC 61375-1 defines five data classes, which shall be supported by ETB:

- Supervisory Data,
- Process Data,
- Message Data,
- Stream Data,
- Best Effort Data.

These data classes shall be mapped to ETB priority classes in IEC 61375-2-3 communication profile and specific definitions of the service parameters shall be done in future IEC 61375-2-4 application profile.

12 ETB Management and monitoring

SNMP shall be used to manage network devices over ETB (see 13.5.2 for ETBN).

When a parameter is defined inside a standard MIB, it shall be read from this standard MIB (not a proprietary one).

Any SNMP manager shall be able to access ETB network MIB variables.

Network monitoring should be done using usual existent network tools to:

- test via ICMP protocol, IP addressing, name resolution and give an idea of latency time,
- verify IP path,
- verify name resolution,
- see and record Ethernet traffic. Port mirroring function should be used to duplicate traffic if necessary,
- verify ED network status (open IP ports, etc.).

13 ETB Application interface

13.1 Contents of this clause

This clause specifies the transmission protocols for the exchange of regular data and event data over the ETB. In order to define these protocols in an abstract way, it is necessary to first define an abstract communication model for the ETB communication. Based on this abstract model, protocols for the transmission of ETB regular data and ETB event data are defined.

13.2 Abstract communication model

In order to define the data exchange over the ETB, an abstract model is needed which hides the specific technologies used for connecting EDs to the ETB (see Figure 53). The communication model used for the definition of ETB communication is depicted in Figure 53. It shows “logical End Devices” connected by any type of Consist Network to the ETBN.

NOTE 1 If CN is based on ECN and ETBN acts as routers, these logical EDs could coincide with physical EDs, but can as well be shared between physical EDs. These EDs are only thought as being the location of source and destination application functions which communicate over the ETB.

NOTE 2 If CN is not based on ECN or ETBN acts as application gateway (between application protocols) these logical EDs coincide with ETBN.

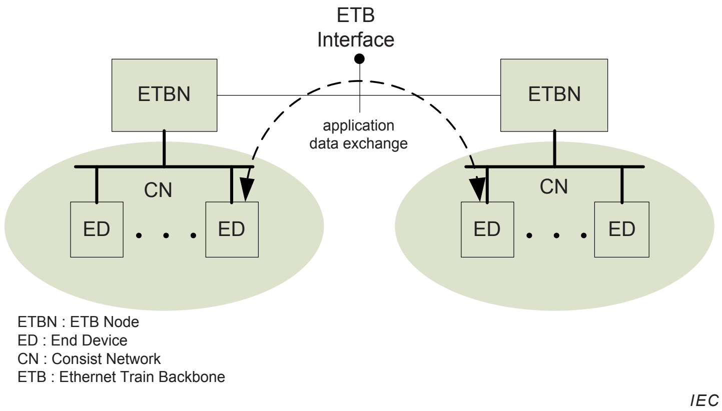


Figure 53 – Abstract communication model for ETB communication

The application functions residing on the logical ED exchange application data over the ETB. Application data are structured into data classes, and different protocols may be used for each data class (see 11.6 for the list of data classes).

13.3 ETB Process Data and Message Data protocols

To exchange data at train application level, a PD/MD protocol shall be used. Application protocol choice is defined in IEC 61375-2-3 (Communication profile).

13.4 ETB protocol transparency

ETB shall be transparent for any application at UDP/TCP level. ETB shall transmit unicast and multicast exchanges.

ETB subnet shall be transparent for usual network protocols: SNMP, DNS, FTP, HTTP, NTP, etc.

ETB subnet shall be transparent for train application protocols: PD/MD, multimedia streaming, etc.

13.5 ETBN interfaces

13.5.1 Application

Inside CN, ETBN shall export an application (TCMS, multimedia, etc.) interface to manage ETB status.

Interfaces:

– ETB status: links status, redundancy, etc.
– Train Topology Discovery results (ordered ETBN list with orientation and CstUUID).

Table 25 gives an example of Train Topology Discovery result:

Table 25 – Train Topology Discovery Object

Consist Number "Subnet Id"	Consist Name	Consist Orientation	CstUUID	LocalFlag (Used to know its own Consist)
1	"consist234"	1	"f81d4fae-7dec-11d0-a765-00a0c91e6bf6"	0
2	"consist124"	0	"ba1d4fae-fcd5-11d0-a765-00b1c91e7cf7"	0
3	"consist78"	1	"f56d4fae-7abc-11d0-a658-00a0c91e1259"	1

When CN is based on Ethernet (ECN), to exchange data with train application the best means is to use train data application PD/MD protocol.

13.5.2 Maintenance and monitoring

13.5.2.1 Network monitoring

ETBN shall implement a SNMPv2 agent (see IETF RFC 1901, RFC 1905 and RFC 1906).

ETBN shall export the following MIBs:

– IEEE8023-LAG-MIB
– IEC 61375-2-5 TTDP-MIB as defined in Annex C

ETBN should export the following MIBs:

– MIB-II (Management Information Base, IETF RFC 1213)
– IF-MIB (Interface group IETF RFC 2863)
– VRRP-MIB (IETF RFC 2787)

13.5.2.2 ETBN Monitoring

ETBN shall implement SSH or telnet/CLI.

13.5.2.3 ETBN Maintenance

ETBN should implement a HTTP server.

The following list of parameters shall be available:

General:

- Manufacturer name,
- Device type,
- Device name,
- Device location,
- Product version,

Status:

- Current Topology Discovery status,
- Current Ethernet ports statuses,

Parameters:

- IPv4 parameters.

ETBN should implement SOAP maintenance Web services.

14 ETB conformity statement

To claim conformance to this standard, equipment are expected to pass a suite of tests. Equipment to be tested shall include:

"Ethernet Train Backbone Node (ETBN): a Train Backbone Node conforming to this standard (train communication network based on Ethernet)."

The conformance test plan for ETB is not in the scope of this standard.

Annex A
(normative)

Summary of ETB sizing parameters

Table A.1 below summarizes the main sizing parameters for ETB architecture:

Table A.1 – ETB sizing parameters

Parameter	Value	Comments
Max nb of ETB / train	4	Related to backbone Id (0 to 3). See 6.4.2.2
Max nb of ETBN / ETB	63	Related to ETBN Id on ETB after Inauguration (1 to 63). See 6.4.2.3.1
Max nb of Consists / train	~ 63	Not specified, but is limited by max nb of ETBN / ETB. 63 Consists is the maximum if there is least one ETBN / Consist
Max nb of ETBN / Consist	32	Related to relative position of an ETBN in a Consist (static configuration, 1 to 32). See "ownEtbnNb" 8.7.6
Max nb of CN / Consist	32	Related to relative CN Id (1 to 32) in a Consist (static configuration, 0 to 31). See "ETBN-CN-CNX" 8.7.6
Max nb of CN / train	63	Related to CN Subnet Id (1 to 63). See 6.4.2.3.1
Max nb of hosts (ED) / ETBN	254	Directly connected hosts to ETB. See 6.5.2
Max nb of hosts / CN	16382	Related to Host Id in CN. See 6.4.2.2
Nb of ports-physical lines / logical link (aggregation group)	1, 2 or 4	See link aggregation, 4.4.2

Annex B
(normative)

Physical topology building algorithm

The UML activity diagram in Figure B.1 below describes (for information only) a possible algorithm to maintain physical topology ("connectivity table"). It relies on TTDP TOPOLOGY frames information with the use of "ETBN Vectors". See 8.7.6 for TOPOLOGY frame fields definitions used below.

This algorithm runs on each ETBN each time a TTDP TOPOLOGY frame event is received. It is described below from a "local ETBN" point of view.

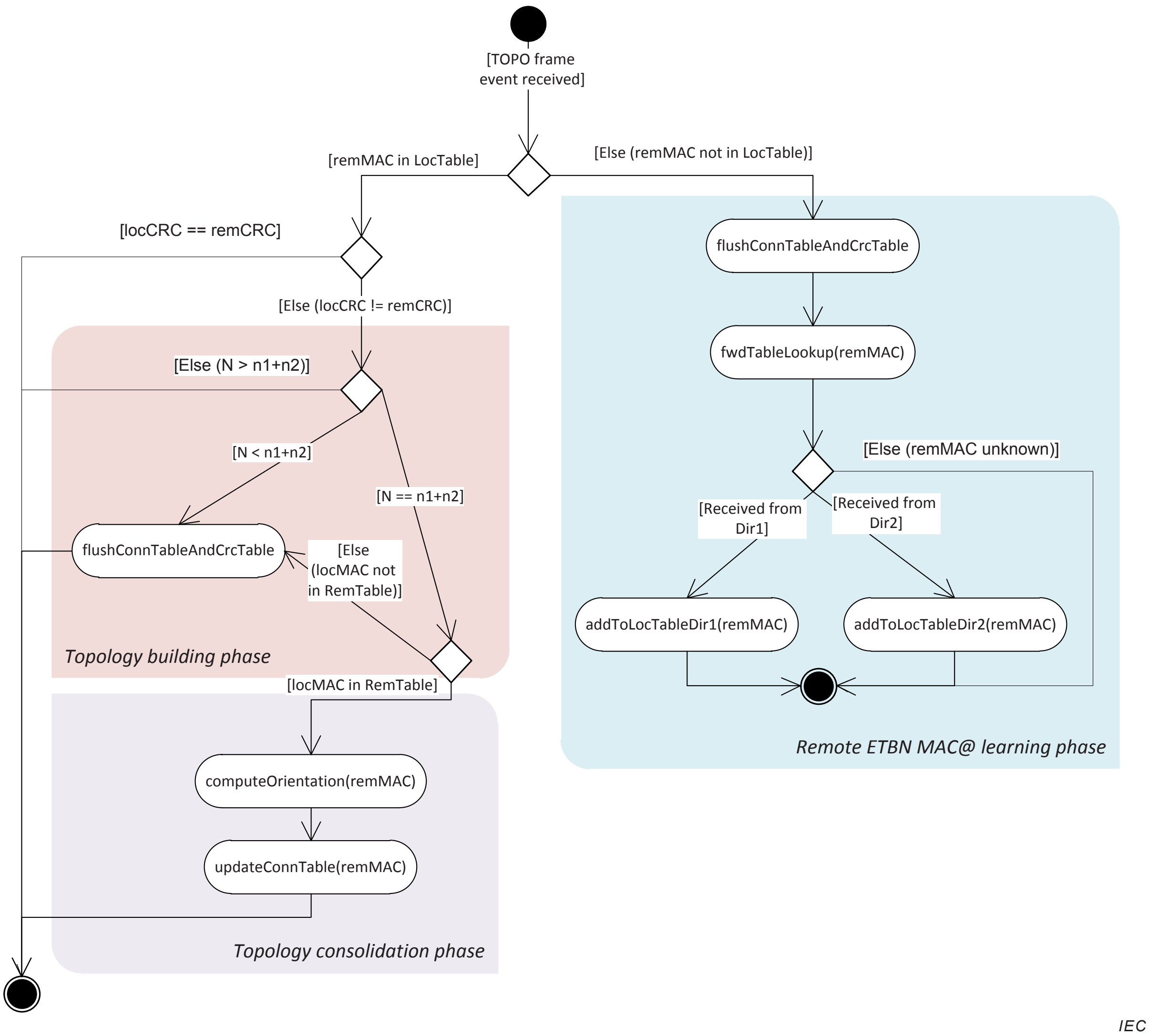


Figure B.1 – Physical topology building

Data:

– **remMAC**: MAC address of remote ETBN which sent the current received TOPOLOGY frame (= ownMacAddr field in received TOPOLOGY frame)

– **locMAC**: MAC address of local ETBN

- **LocTableDir1**: local unordered list of ETBNs seen in Dir1 of local ETBN (ETBN Vector for Dir1 direction to be sent in TOPOLOGY frame)
- **LocTableDir2**: local unordered list of ETBNs seen in Dir2 of local ETBN (ETBN Vector for Dir2 direction to be sent in TOPOLOGY frame)
- **LocTable**: union of LocTableDir1 and LocTableDir2
- **N1**: number of ETBNs in LocTableDir1
- **N2**: number of ETBNs in LocTableDir2
- **N**: number of ETBNs in LocTable, N = N1 + N2
- **RemTableDir1**: received unordered list of ETBNs seen in Dir1 of remote ETBN (ETBN Vector for Dir1 direction in received TOPOLOGY frame)
- **RemTableDir2**: received unordered list of ETBNs seen in Dir2 of remote ETBN (ETBN Vector for Dir2 direction in received TOPOLOGY frame)
- **RemTable**: union of RemTableDir1 and RemTableDir2
- **remCRC**: CRC of remote connectivity table (connTableCrc32 field from received TOPOLOGY frame)
- **n1**: number of ETBNs in RemTableDir1
- **n2**: number of ETBNs in RemTableDir2
- **n**: number of ETBNs in RemTable, n = n1 + n2
- **ConnTable**: local ETB connectivity table
- **locCRC**: CRC of local connectivity table ConnTable (connTableCrc32 field of TOPOLOGY frame to be sent)
- **CRCTable**: list of received CRC (remote ETBN connectivity tables CRC)
- **Orientation**: ordered list of remote ETBN orientations

Conditions:

- **TOPO frame event received**: a TTDP TOPOLOGY frame was received or a validity timeout has elapsed on a previously received TOPOLOGY frame.
- **Else (remMAC not in LocTable)**: received the TOPOLOGY frame with an unknown ETBN MAC address. This ETBN is a newcomer and we must determine where it is located on the ETB. If we succeed, we store its MAC address in the intended LocTable (Dir1 or Dir2). This branch is also followed when a validity timeout has elapsed. In this case, remMAC is considered unknown which leads to flush ConnTable and CRCTable.
- **Else (remMAC unknown)**: received MAC address not yet in local ETBN switch forwarding table (should not happen when TOPOLOGY frame received).
- **Received from Dir1**: the TOPOLOGY frame was received from the Dir1 side of the local ETBN.
- **Received from Dir2**: the TOPOLOGY frame was received from the Dir2 side of the local ETBN.
- **remMAC in LocTable**: received the TOPOLOGY frame with a known ETBN MAC address.
- **locCRC == remCRC**: the received connectivity table CRC is the same as the local connectivity table CRC. All ETBNs share the same physical topology, nothing to do.
- **Else (locCRC != remCRC)**: the received connectivity table CRC is not the same as the local connectivity table CRC. ETBN do not share the same physical topology yet. Local connectivity table will have to be updated.
- **Else (N > n1+n2)**: local ETBN knows more ETBNs than the remote ETBN in the received TOPOLOGY frame. We ignore the received topology information.
- **N < n1+n2**: the remote ETBN knows more ETBNs than local ETBN. We can reset our local ordered topology information, wait and learn from TOPOLOGY frames to come. This way, we can avoid handling insertions in local connectivity table, wait for all nodes to be known and then update local topology more easily.

– **N == n1+n2**: the local and remote ETBN knows the same number of ETBNs.

– **Else (locMAC not in RemTable)**: local ETBN MAC address is not in the received ETBN Vectors (which means that the remote ETBN knows an ETBN we do not know). We can reset our local ordered topology information.

– **locMAC in RemTable**: local ETBN MAC address is in the received ETBN Vectors. We can process the received ETBN information and update our local connectivity table.

Actions:

– **flushConnTableAndCrcTable**: reset local connectivity table ConnTable to its default value and reset locCRC to its default value (as if own ETBN alone, see 8.8.4). Also empty received CRC table.

– **fwdTableLookup(remMAC)**: look for the received TOPOLOGY frame MAC address in local ETBN switch forwarding tables to determine its ingress direction.

– **addToLocTableDir1(remMAC) / addToLocTableDir2(remMAC)**: add the received MAC address in local ETBN Dir1/Dir2 list and increment its count (n1:= n1 + 1 / n2:= n2 + 1).

– **computeOrientation(remMAC)**: compute orientation of the remote ETBN relative to local orientation

```
IF      (remMAC in LocTableDir1) AND (locMAC in RemTableDir2) THEN
     orientation:= same
ELSE IF (remMAC in LocTableDir2) AND (locMAC in RemTableDir1) THEN
     orientation:= same
ELSE IF (remMAC in LocTableDir1) AND (locMAC in RemTableDir1) THEN
     orientation:= opposite
ELSE IF (remMAC in LocTableDir2) AND (locMAC in RemTableDir2) THEN
     orientation:= opposite
ENDIF
```

– **updateConnTable(remMAC)**: update physical topology information

```
IF (orientation == same) THEN
     ConnTable[n1]  := remMAC
     Orientation[n1]:= orientation
ELSE
     ConnTable[n2]  := remMAC
     Orientation[n2]:= orientation
ENDIF
Compute new locCRC from updated ConnTable
```

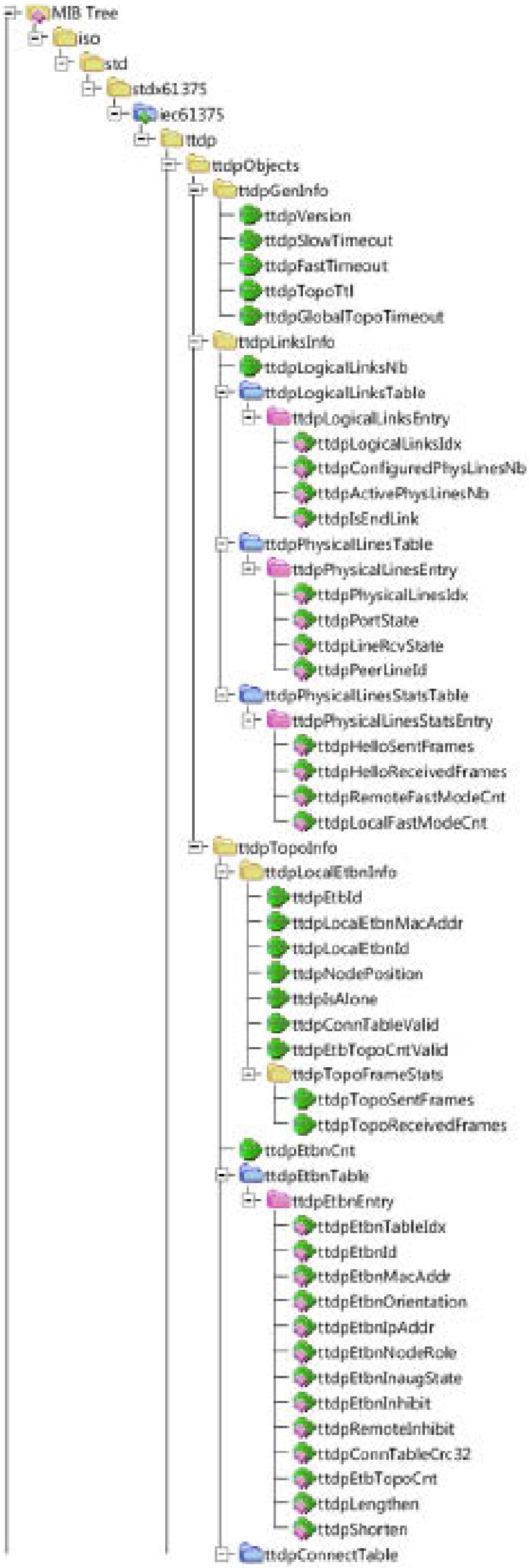
NOTE When all ETBNs are known (i.e. in "consolidation phase"), n1 or n2 (according to orientation) directly gives the remote ETBN position on ETB.

Annex C
(normative)

TTDP MIB definition

This annex contains the definition for IEC 61375-2-5 TTDP-MIB.

The tree view of the MIB is (Figure C.1):


MIB Tree
iso
std
stdx61375
iec61375
ttdp
ttdpObjects
ttdpGenInfo
ttdpVersion
ttdpSlowTimeout
ttdpFastTimeout
ttdpTopoTtl
ttdpGlobalTopoTimeout
ttdpLinksInfo
ttdpLogicalLinksNb
ttdpLogicalLinksTable
ttdpLogicalLinksEntry
ttdpLogicalLinksIdx
ttdpConfiguredPhysLinesNb
ttdpActivePhysLinesNb
ttdpIsEndLink
ttdpPhysicalLinesTable
ttdpPhysicalLinesEntry
ttdpPhysicalLinesIdx
ttdpPortState
ttdpLineRcvState
ttdpPeerLineId
ttdpPhysicalLinesStatsTable
ttdpPhysicalLinesStatsEntry
ttdpHelloSentFrames
ttdpHelloReceivedFrames
ttdpRemoteFastModeCnt
ttdpLocalFastModeCnt
ttdpTopoInfo
ttdpLocalEtbnInfo
ttdpEtbId
ttdpLocalEtbnMacAddr
ttdpLocalEtbnId
ttdpNodePosition
ttdpIsAlone
ttdpConnTableValid
ttdpEtbTopoCntValid
ttdpTopoFrameStats
ttdpTopoSentFrames
ttdpTopoReceivedFrames
ttdpEtbnCnt
ttdpEtbnTable
ttdpEtbnEntry
ttdpEtbnTableIdx
ttdpEtbnId
ttdpEtbnMacAddr
ttdpEtbnOrientation
ttdpEtbnIpAddr
ttdpEtbnNodeRole
ttdpEtbnInaugState
ttdpEtbnInhibit
ttdpRemoteInhibit
ttdpConnTableCrc32
ttdpEtbTopoCnt
ttdpLengthen
ttdpShorten
ttdpConnectTable

IEC

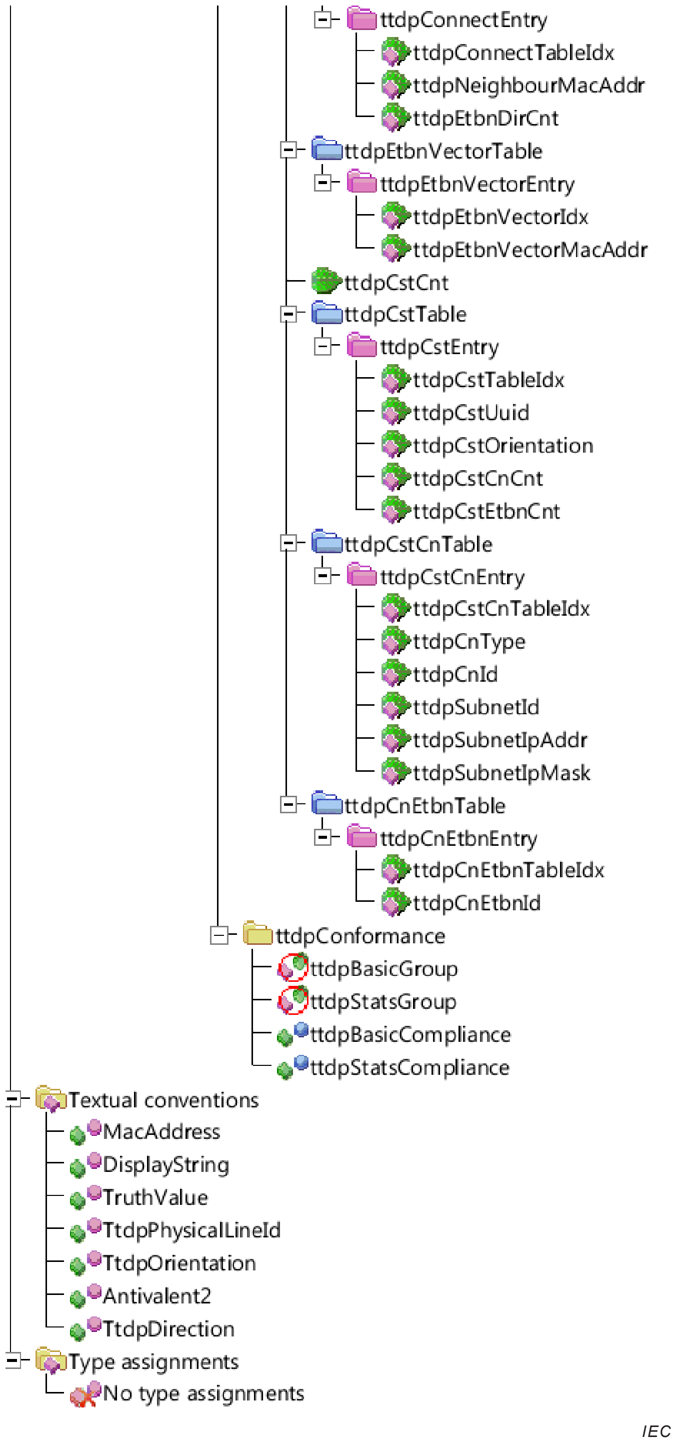


Figure C.1 – TTDP MIB tree view

The detailed ASN.1 description is the following:

```
--
-- MIB generated
-- Monday, February 25, 2013 at 13:39:53
--

     TTDP-MIB DEFINITIONS::= BEGIN

          IMPORTS
               OBJECT-GROUP, MODULE-COMPLIANCE
                    FROM SNMPv2-CONF
               iso, IpAddress, Integer32, Unsigned32, OBJECT-TYPE,
               MODULE-IDENTITY
                    FROM SNMPv2-SMI
               MacAddress, TruthValue, TEXTUAL-CONVENTION
                    FROM SNMPv2-TC;


-- ******************************************************************
-- Root OID
-- ******************************************************************
-- January 07, 2013
          -- 1.0.61375.2
          iec61375 MODULE-IDENTITY
               LAST-UPDATED "201212211751Z"          -- December 21, 2012 at 17:51
GMT
               ORGANIZATION
                    "IEC"
               CONTACT-INFO
                    "International Electrotechnical Commission
                    IEC Central Office
                    3, rue de Varembé
                    P.O. Box 131
                    CH – 1211 GENEVA 20
                    Switzerland
                    Phone: +41 22 919 02 11
                    Fax: +41 22 919 03 00
                    email: info@iec.ch"
               DESCRIPTION
                    "This MIB module defines the Network Management interfaces
                    for the TTDP protocol defined by the IEC standard 61375-2-5.

                    This definition specifies a pure monitoring variant of a SNMP
entity."
               ::= { stdx61375 2 }



--
-- Textual conventions
--

          TtdpPhysicalLineId::= TEXTUAL-CONVENTION
               STATUS current
               DESCRIPTION
                    "Represents TTDP physical line Identifier (A, B, C, D or none)."
               SYNTAX INTEGER
                    {
                    lineNone(45),
                    lineA(65),
                    lineB(66),
                    lineC(67),
                    lineD(68)
                    }

          TtdpOrientation::= TEXTUAL-CONVENTION
               STATUS current
               DESCRIPTION
                    "Represents orientation of an ETBN or a Consist"
               SYNTAX INTEGER
                    {
                    direct(1),
                    inverse(2),
                    undefined(3)
                    }

          Antivalent2::= TEXTUAL-CONVENTION
```

```
                STATUS current
                DESCRIPTION
                     "Definition of ANTIVALENT2 type."
                SYNTAX INTEGER
                     {
                     error(0),
                     false(1),
                     true(2),
                     undefined(3)
                     }

           TtdpDirection::= TEXTUAL-CONVENTION
                STATUS current
                DESCRIPTION
                     "Represents an ETB direction."
                SYNTAX INTEGER
                     {
                     dir1(1),
                     dir2(2)
                     }


--
-- Node definitions
--

           -- 1.0
           std OBJECT IDENTIFIER::= { iso 0 }


           -- 1.0.61375
           stdx61375 OBJECT IDENTIFIER::= { std 61375 }


-- *********************************************************************
-- TTDP Protocol
-- *********************************************************************
           -- 1.0.61375.2.5
           ttdp OBJECT IDENTIFIER::= { iec61375 5 }


-- *********************************************************************
-- objects groups of TTDP object identifiers
-- *********************************************************************
           -- 1.0.61375.2.5.1
           ttdpObjects OBJECT IDENTIFIER::= { ttdp 1 }


-- ETBN TTDP general information.
           -- 1.0.61375.2.5.1.1
           ttdpGenInfo OBJECT IDENTIFIER::= { ttdpObjects 1 }


           -- 1.0.61375.2.5.1.1.1
           ttdpVersion OBJECT-TYPE
                SYNTAX Unsigned32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "TTDP protocol version.

                     Interpreted version string is 'M.m.r.n' for raw value 'Mmrn'H.
                     First version is '1.0.0.0'."
                ::= { ttdpGenInfo 1 }


           -- 1.0.61375.2.5.1.1.2
           ttdpSlowTimeout OBJECT-TYPE
                SYNTAX Unsigned32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "TTDP HELLO frames slow timeout in ms."
                ::= { ttdpGenInfo 2 }


           -- 1.0.61375.2.5.1.1.3
           ttdpFastTimeout OBJECT-TYPE
```

```
                SYNTAX Unsigned32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "TTDP HELLO frames fast timeout in ms."
                ::= { ttdpGenInfo 3 }


           -- 1.0.61375.2.5.1.1.4
           ttdpTopoTtl OBJECT-TYPE
                SYNTAX Unsigned32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "TTDP TOPOLOGY frames TTL in ms."
                ::= { ttdpGenInfo 4 }


           -- 1.0.61375.2.5.1.1.5
           ttdpGlobalTopoTimeout OBJECT-TYPE
                SYNTAX Unsigned32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "global TTDP TOPOLOGY frames timeout in ms."
                ::= { ttdpGenInfo 5 }


-- ETBN ETB links information.
           -- 1.0.61375.2.5.1.3
           ttdpLinksInfo OBJECT IDENTIFIER::= { ttdpObjects 3 }


           -- 1.0.61375.2.5.1.3.1
           ttdpLogicalLinksNb OBJECT-TYPE
                SYNTAX Unsigned32 (2)
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "Number of ETBN logical links connected to ETB.

                     Must always be 2."
                ::= { ttdpLinksInfo 1 }


           -- 1.0.61375.2.5.1.3.2
           ttdpLogicalLinksTable OBJECT-TYPE
                SYNTAX SEQUENCE OF TtdpLogicalLinksEntry
                MAX-ACCESS not-accessible
                STATUS current
                DESCRIPTION
                     "ETBN ETB logical links table.

                     There are always 2 directions (dir1, dir2) for each ETBN."
                ::= { ttdpLinksInfo 2 }


           -- 1.0.61375.2.5.1.3.2.1
           ttdpLogicalLinksEntry OBJECT-TYPE
                SYNTAX TtdpLogicalLinksEntry
                MAX-ACCESS not-accessible
                STATUS current
                DESCRIPTION
                     "Entry for an ETBN logical links table."
                INDEX { ttdpLogicalLinksIdx }
                ::= { ttdpLogicalLinksTable 1 }


           TtdpLogicalLinksEntry::=
                SEQUENCE {
                     ttdpLogicalLinksIdx
                          TtdpDirection,
                     ttdpConfiguredPhysLinesNb
                          Unsigned32,
                     ttdpActivePhysLinesNb
                          Unsigned32,
                     ttdpIsEndLink
                          TruthValue
```

```
                }

        -- 1.0.61375.2.5.1.3.2.1.1
        ttdpLogicalLinksIdx OBJECT-TYPE
            SYNTAX TtdpDirection
            MAX-ACCESS read-only
            STATUS current
            DESCRIPTION
                "Link index in logical link table.

                1 is for dir1, 2 for dir2 of the ETBN."
            ::= { ttdpLogicalLinksEntry 1 }


        -- 1.0.61375.2.5.1.3.2.1.2
        ttdpConfiguredPhysLinesNb OBJECT-TYPE
            SYNTAX Unsigned32 (1..4)
            MAX-ACCESS read-only
            STATUS current
            DESCRIPTION
                "Number of statically defined physical lines in LAG."
            ::= { ttdpLogicalLinksEntry 2 }


        -- 1.0.61375.2.5.1.3.2.1.3
        ttdpActivePhysLinesNb OBJECT-TYPE
            SYNTAX Unsigned32 (0..4)
            MAX-ACCESS read-only
            STATUS current
            DESCRIPTION
                "Number of active physical lines in LAG."
            ::= { ttdpLogicalLinksEntry 3 }


        -- 1.0.61375.2.5.1.3.2.1.4
        ttdpIsEndLink OBJECT-TYPE
            SYNTAX TruthValue
            MAX-ACCESS read-only
            STATUS current
            DESCRIPTION
                "Logical link extremity status.

                true when logical link is an ETB end link, else false."
            ::= { ttdpLogicalLinksEntry 4 }


        -- 1.0.61375.2.5.1.3.3
        ttdpPhysicalLinesTable OBJECT-TYPE
            SYNTAX SEQUENCE OF TtdpPhysicalLinesEntry
            MAX-ACCESS not-accessible
            STATUS current
            DESCRIPTION
                "Physical lines table for an ETB direction."
            ::= { ttdpLinksInfo 3 }


        -- 1.0.61375.2.5.1.3.3.1
        ttdpPhysicalLinesEntry OBJECT-TYPE
            SYNTAX TtdpPhysicalLinesEntry
            MAX-ACCESS not-accessible
            STATUS current
            DESCRIPTION
                "Physical lines table entry.

                ttdpLogicalLinksIdx    is    the    first    level    index    in
ttdpLogicalLinksTable,
                ttdpPhysicalLinesIdx    is    the    second    level    index    in
ttdpPhysicalLinesTable."
            INDEX { ttdpLogicalLinksIdx, ttdpPhysicalLinesIdx }
            ::= { ttdpPhysicalLinesTable 1 }


        TtdpPhysicalLinesEntry::=
            SEQUENCE {
                ttdpPhysicalLinesIdx
                    TtdpPhysicalLineId,
                ttdpPortState
                    INTEGER,
```

```
                    ttdpLineRcvState
                         INTEGER,
                    ttdpPeerLineId
                         TtdpPhysicalLineId
                }

          -- 1.0.61375.2.5.1.3.3.1.1
          ttdpPhysicalLinesIdx OBJECT-TYPE
               SYNTAX TtdpPhysicalLineId
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "Line index in physical lines table.

                    None value is not allowed (only line A, B, C or D).

                    "
               ::= { ttdpPhysicalLinesEntry 1 }


          -- 1.0.61375.2.5.1.3.3.1.2
          ttdpPortState OBJECT-TYPE
               SYNTAX INTEGER
                    {
                    disabled(0),
                    forwarding(2),
                    discarding(3)
                    }
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "TTDP switch port state."
               ::= { ttdpPhysicalLinesEntry 2 }


          -- 1.0.61375.2.5.1.3.3.1.3
          ttdpLineRcvState OBJECT-TYPE
               SYNTAX INTEGER
                    {
                    lineNotOK(1),
                    lineOK(2),
                    notAvailable(3)
                    }
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "Physical  line  status  (according  to  TTDP  HELLO  frames  received
and port status)."
               ::= { ttdpPhysicalLinesEntry 3 }


          -- 1.0.61375.2.5.1.3.3.1.4
          ttdpPeerLineId OBJECT-TYPE
               SYNTAX TtdpPhysicalLineId
               MAX-ACCESS read-write
               STATUS current
               DESCRIPTION
                    "Physical line distant (peer) ID."
               ::= { ttdpPhysicalLinesEntry 4 }


          -- 1.0.61375.2.5.1.3.4
          ttdpPhysicalLinesStatsTable OBJECT-TYPE
               SYNTAX SEQUENCE OF TtdpPhysicalLinesStatsEntry
               MAX-ACCESS not-accessible
               STATUS current
               DESCRIPTION
                    "Physical lines statistics table for physical lines (optional)."
               ::= { ttdpLinksInfo 4 }


          -- 1.0.61375.2.5.1.3.4.1
          ttdpPhysicalLinesStatsEntry OBJECT-TYPE
               SYNTAX TtdpPhysicalLinesStatsEntry
               MAX-ACCESS not-accessible
               STATUS current
               DESCRIPTION
                    "Physical line statistics table entry.
```

```
                      ttdpLogicalLinksIdx    is    the    first    level    index    in
ttdpLogicalLinksTable,
                      ttdpPhysicalLinesIdx    is    the    second    level    index    in
ttdpPhysicalLinesStatsTable."
                INDEX { ttdpLogicalLinksIdx, ttdpPhysicalLinesIdx }
                ::= { ttdpPhysicalLinesStatsTable 1 }


           TtdpPhysicalLinesStatsEntry::=
                SEQUENCE {
                      ttdpHelloSentFrames
                           Integer32,
                      ttdpHelloReceivedFrames
                           Integer32,
                      ttdpRemoteFastModeCnt
                           Integer32,
                      ttdpLocalFastModeCnt
                           Integer32
                 }

           -- 1.0.61375.2.5.1.3.4.1.1
           ttdpHelloSentFrames OBJECT-TYPE
                SYNTAX Integer32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                      "Number of HELLO frames sent on this line

                      Optional, = -1 if not provided."
                ::= { ttdpPhysicalLinesStatsEntry 1 }


           -- 1.0.61375.2.5.1.3.4.1.2
           ttdpHelloReceivedFrames OBJECT-TYPE
                SYNTAX Integer32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                      "Number of HELLO frames received on this line

                      Optional, = -1 if not provided."
                ::= { ttdpPhysicalLinesStatsEntry 2 }


           -- 1.0.61375.2.5.1.3.4.1.3
           ttdpRemoteFastModeCnt OBJECT-TYPE
                SYNTAX Integer32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                      "Number of times fast mode was activated on peer.

                      Optional, = -1 if not provided."
                ::= { ttdpPhysicalLinesStatsEntry 3 }


           -- 1.0.61375.2.5.1.3.4.1.4
           ttdpLocalFastModeCnt OBJECT-TYPE
                SYNTAX Integer32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                      "Number  of  times  fast  mode  was  locally  entered  (activated  by
peer).

                      Optional, = -1 if not provided."
                ::= { ttdpPhysicalLinesStatsEntry 4 }


-- ETBN TTDP TOPOLOGY information.
           -- 1.0.61375.2.5.1.5
           ttdpTopoInfo OBJECT IDENTIFIER::= { ttdpObjects 5 }


-- Local ETBN information
           -- 1.0.61375.2.5.1.5.1
           ttdpLocalEtbnInfo OBJECT IDENTIFIER::= { ttdpTopoInfo 1 }
```

```
        -- 1.0.61375.2.5.1.5.1.1
        ttdpEtbId OBJECT-TYPE
              SYNTAX Unsigned32 (1..4)
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "ETB number on which local ETBN is connected to."
              ::= { ttdpLocalEtbnInfo 1 }


        -- 1.0.61375.2.5.1.5.1.2
        ttdpLocalEtbnMacAddr OBJECT-TYPE
              SYNTAX MacAddress
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "Local ETBN MAC address."
              ::= { ttdpLocalEtbnInfo 2 }


        -- 1.0.61375.2.5.1.5.1.3
        ttdpLocalEtbnId OBJECT-TYPE
              SYNTAX Unsigned32 (1..63)
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "Local ETBN number on ETB."
              ::= { ttdpLocalEtbnInfo 3 }


        -- 1.0.61375.2.5.1.5.1.4
        ttdpNodePosition OBJECT-TYPE
              SYNTAX INTEGER
                    {
                    intermediate(0),
                    extremity1(1),
                    extremity2(2)
                    }
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "Node position on ETB."
              ::= { ttdpLocalEtbnInfo 4 }


        -- 1.0.61375.2.5.1.5.1.5
        ttdpIsAlone OBJECT-TYPE
              SYNTAX TruthValue
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "Flag which tells whether ETBN node is alone on ETB."
              ::= { ttdpLocalEtbnInfo 5 }


        -- 1.0.61375.2.5.1.5.1.6
        ttdpConnTableValid OBJECT-TYPE
              SYNTAX TruthValue
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "Flag  which  describes  whether  physical  topology  is  stable  or
not."
              ::= { ttdpLocalEtbnInfo 6 }


        -- 1.0.61375.2.5.1.5.1.7
        ttdpEtbTopoCntValid OBJECT-TYPE
              SYNTAX TruthValue
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "Flag which describes whether logical topology is stable or not."
              ::= { ttdpLocalEtbnInfo 7 }
```

```
-- Statistics on local ETBN TOPOLOGY frames (optional)
           -- 1.0.61375.2.5.1.5.1.8
           ttdpTopoFrameStats OBJECT IDENTIFIER::= { ttdpLocalEtbnInfo 8 }


           -- 1.0.61375.2.5.1.5.1.8.1
           ttdpTopoSentFrames OBJECT-TYPE
                SYNTAX Integer32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "Number of TOPOLOGY frames sent from this node.

                     = -1 if not provided."
                ::= { ttdpTopoFrameStats 1 }


           -- 1.0.61375.2.5.1.5.1.8.2
           ttdpTopoReceivedFrames OBJECT-TYPE
                SYNTAX Integer32
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "Number of TOPOLOGY frames received on this node.

                     = -1 if not provided."
                ::= { ttdpTopoFrameStats 2 }


           -- 1.0.61375.2.5.1.5.2
           ttdpEtbnCnt OBJECT-TYPE
                SYNTAX Unsigned32 (1..63)
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "Number of ETBN on ETB."
                ::= { ttdpTopoInfo 2 }


           -- 1.0.61375.2.5.1.5.3
           ttdpEtbnTable OBJECT-TYPE
                SYNTAX SEQUENCE OF TtdpEtbnEntry
                MAX-ACCESS not-accessible
                STATUS current
                DESCRIPTION
                     "corrected  physical  topology  (connectivity  table)  +  some  more
info."
                ::= { ttdpTopoInfo 3 }


           -- 1.0.61375.2.5.1.5.3.1
           ttdpEtbnEntry OBJECT-TYPE
                SYNTAX TtdpEtbnEntry
                MAX-ACCESS not-accessible
                STATUS current
                DESCRIPTION
                     "Entry for corrected physical topology (connectivity table)."
                INDEX { ttdpEtbnTableIdx }
                ::= { ttdpEtbnTable 1 }


           TtdpEtbnEntry::=
                SEQUENCE {
                     ttdpEtbnTableIdx
                          Unsigned32,
                     ttdpEtbnId
                          Unsigned32,
                     ttdpEtbnMacAddr
                          MacAddress,
                     ttdpEtbnOrientation
                          TtdpOrientation,
                     ttdpEtbnIpAddr
                          IpAddress,
                     ttdpEtbnNodeRole
                          INTEGER,
                     ttdpEtbnInaugState
                          INTEGER,
                     ttdpEtbnInhibit
```

```
                    TruthValue,
               ttdpRemoteInhibit
                    TruthValue,
               ttdpConnTableCrc32
                    Unsigned32,
               ttdpEtbTopoCnt
                    Unsigned32,
               ttdpLengthen
                    Antivalent2,
               ttdpShorten
                    Antivalent2
           }

     -- 1.0.61375.2.5.1.5.3.1.1
     ttdpEtbnTableIdx OBJECT-TYPE
          SYNTAX Unsigned32 (1..63)
          MAX-ACCESS read-only
          STATUS current
          DESCRIPTION
               "ETBN index in ttdpEtbnTable (physical topology)."
          ::= { ttdpEtbnEntry 1 }


     -- 1.0.61375.2.5.1.5.3.1.2
     ttdpEtbnId OBJECT-TYPE
          SYNTAX Unsigned32 (0..63)
          MAX-ACCESS read-only
          STATUS current
          DESCRIPTION
               "ETBN ID on ETB.

               1..N ETBN are ordered from lowest cstUUID toward direction2 for
ascending ETBN Ids,
               0 for a missing ETBN (corrected topology)."
          ::= { ttdpEtbnEntry 2 }


     -- 1.0.61375.2.5.1.5.3.1.3
     ttdpEtbnMacAddr OBJECT-TYPE
          SYNTAX MacAddress
          MAX-ACCESS read-only
          STATUS current
          DESCRIPTION
               "ETBN MAC address.

               NULL if ETBN not present in case of corrected topology."
          ::= { ttdpEtbnEntry 3 }


     -- 1.0.61375.2.5.1.5.3.1.4
     ttdpEtbnOrientation OBJECT-TYPE
          SYNTAX TtdpOrientation
          MAX-ACCESS read-only
          STATUS current
          DESCRIPTION
               "ETBN orientation."
          ::= { ttdpEtbnEntry 4 }


     -- 1.0.61375.2.5.1.5.3.1.5
     ttdpEtbnIpAddr OBJECT-TYPE
          SYNTAX IpAddress
          MAX-ACCESS read-only
          STATUS current
          DESCRIPTION
               "ETBN IP address on ETB.

               NULL if not defined."
          ::= { ttdpEtbnEntry 5 }


     -- 1.0.61375.2.5.1.5.3.1.6
     ttdpEtbnNodeRole OBJECT-TYPE
          SYNTAX INTEGER
               {
               undefined(0),
               master(1),
               backup(2),
```

```
                    notRedundant(3)
                    }
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "ETBN node role."
               ::= { ttdpEtbnEntry 6 }


          -- 1.0.61375.2.5.1.5.3.1.7
          ttdpEtbnInaugState OBJECT-TYPE
               SYNTAX INTEGER
                    {
                    init(0),
                    notInaugurated(1),
                    inaugurated(2),
                    readyForInauguration(3)
                    }
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "ETBN inauguration state."
               ::= { ttdpEtbnEntry 7 }


          -- 1.0.61375.2.5.1.5.3.1.8
          ttdpEtbnInhibit OBJECT-TYPE
               SYNTAX TruthValue
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "Inhibit request from this node.

                    Inauguration allowed true or false."
               ::= { ttdpEtbnEntry 8 }


          -- 1.0.61375.2.5.1.5.3.1.9
          ttdpRemoteInhibit OBJECT-TYPE
               SYNTAX TruthValue
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "Remote composition inhibition.

                    Inauguration allowed true or false."
               ::= { ttdpEtbnEntry 9 }


          -- 1.0.61375.2.5.1.5.3.1.10
          ttdpConnTableCrc32 OBJECT-TYPE
               SYNTAX Unsigned32
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "CRC32  of  raw  physical  topology  (connectivity  table),  not
corrected."
               ::= { ttdpEtbnEntry 10 }


          -- 1.0.61375.2.5.1.5.3.1.11
          ttdpEtbTopoCnt OBJECT-TYPE
               SYNTAX Unsigned32
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "CRC32 of logical topology (Train Network Directory)."
               ::= { ttdpEtbnEntry 11 }


          -- 1.0.61375.2.5.1.5.3.1.12
          ttdpLengthen OBJECT-TYPE
               SYNTAX Antivalent2
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "Lengthen flag.
```

```
                    1(false)=stable length,
                    2(true)=lengthening,
                    3(undefined)=undefined."
               ::= { ttdpEtbnEntry 12 }


          -- 1.0.61375.2.5.1.5.3.1.13
          ttdpShorten OBJECT-TYPE
               SYNTAX Antivalent2
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "Shorten flag.

                    1(false)=stable length,
                    2(true)=shortening,
                    3(undefined)=undefined."
               ::= { ttdpEtbnEntry 13 }


          -- 1.0.61375.2.5.1.5.4
          ttdpConnectTable OBJECT-TYPE
               SYNTAX SEQUENCE OF TtdpConnectEntry
               MAX-ACCESS not-accessible
               STATUS current
               DESCRIPTION
                    "Connection  table  for  ETBNs  in  each  ETB  directions  (always  2
directions).

                    Contains "connectivity vector" and "ETBN vector" for each ETBN"
               ::= { ttdpTopoInfo 4 }


          -- 1.0.61375.2.5.1.5.4.1
          ttdpConnectEntry OBJECT-TYPE
               SYNTAX TtdpConnectEntry
               MAX-ACCESS not-accessible
               STATUS current
               DESCRIPTION
                    "Connection table entry.

                    ttdpEtbnTableIdx is the first level index in ttdpEtbnTable,
                    ttdpConnectTableIdx    is    the    second    level    index    in
ttdpConnectTable."
               INDEX { ttdpEtbnTableIdx, ttdpConnectTableIdx }
               ::= { ttdpConnectTable 1 }


          TtdpConnectEntry::=
               SEQUENCE {
                    ttdpConnectTableIdx
                         TtdpDirection,
                    ttdpNeighbourMacAddr
                         MacAddress,
                    ttdpEtbnDirCnt
                         Unsigned32
                }

          -- 1.0.61375.2.5.1.5.4.1.1
          ttdpConnectTableIdx OBJECT-TYPE
               SYNTAX TtdpDirection
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "Direction index in ttdpConnecttable."
               ::= { ttdpConnectEntry 1 }


          -- 1.0.61375.2.5.1.5.4.1.2
          ttdpNeighbourMacAddr OBJECT-TYPE
               SYNTAX MacAddress
               MAX-ACCESS read-only
               STATUS current
               DESCRIPTION
                    "MAC address of direct ETBN neighbour in this direction."
               ::= { ttdpConnectEntry 2 }
```

```
        -- 1.0.61375.2.5.1.5.4.1.3
        ttdpEtbnDirCnt OBJECT-TYPE
            SYNTAX Unsigned32 (0..62)
            MAX-ACCESS read-only
            STATUS current
            DESCRIPTION
                "Number of ETBNs in this direction."
            ::= { ttdpConnectEntry 3 }


        -- 1.0.61375.2.5.1.5.5
        ttdpEtbnVectorTable OBJECT-TYPE
            SYNTAX SEQUENCE OF TtdpEtbnVectorEntry
            MAX-ACCESS not-accessible
            STATUS current
            DESCRIPTION
                "Table of "ETBN vectors" for each ETBN in each direction."
            ::= { ttdpTopoInfo 5 }


        -- 1.0.61375.2.5.1.5.5.1
        ttdpEtbnVectorEntry OBJECT-TYPE
            SYNTAX TtdpEtbnVectorEntry
            MAX-ACCESS not-accessible
            STATUS current
            DESCRIPTION
                "ETBN vectors table entry.

                ttdpEtbnTableIdx is the first level index in ttdpEtbnTable,
                ttdpConnectTableIdx    is    the    second    level    index    in
ttdpConnectTable,
                ttdpEtbnVectorIdx    is    the    third    level    index    in
ttdpEtbnVectorTable"
            INDEX { ttdpEtbnTableIdx, ttdpConnectTableIdx, ttdpEtbnVectorIdx }
            ::= { ttdpEtbnVectorTable 1 }


        TtdpEtbnVectorEntry::=
            SEQUENCE {
                ttdpEtbnVectorIdx
                    Unsigned32,
                ttdpEtbnVectorMacAddr
                    MacAddress
             }

        -- 1.0.61375.2.5.1.5.5.1.1
        ttdpEtbnVectorIdx OBJECT-TYPE
            SYNTAX Unsigned32 (1..62)
            MAX-ACCESS read-only
            STATUS current
            DESCRIPTION
                "Index of ETBN in ttdpEtbnVector."
            ::= { ttdpEtbnVectorEntry 1 }


        -- 1.0.61375.2.5.1.5.5.1.2
        ttdpEtbnVectorMacAddr OBJECT-TYPE
            SYNTAX MacAddress
            MAX-ACCESS read-only
            STATUS current
            DESCRIPTION
                "ETBN MAC address."
            ::= { ttdpEtbnVectorEntry 2 }


        -- 1.0.61375.2.5.1.5.6
        ttdpCstCnt OBJECT-TYPE
            SYNTAX Unsigned32 (1..31)
            MAX-ACCESS read-only
            STATUS current
            DESCRIPTION
                "Number of Consists in train."
            ::= { ttdpTopoInfo 6 }


        -- 1.0.61375.2.5.1.5.7
        ttdpCstTable OBJECT-TYPE
            SYNTAX SEQUENCE OF TtdpCstEntry
```

```
                MAX-ACCESS not-accessible
                STATUS current
                DESCRIPTION
                     "Consist  table:  logical  topology  =  Train  Network  Directory
(TNDir) + some more info.

                     Organized conforming to the 3 levels of TNDir."
                ::= { ttdpTopoInfo 7 }


          -- 1.0.61375.2.5.1.5.7.1
          ttdpCstEntry OBJECT-TYPE
                SYNTAX TtdpCstEntry
                MAX-ACCESS not-accessible
                STATUS current
                DESCRIPTION
                     "Entry for Consist table."
                INDEX { ttdpCstTableIdx }
                ::= { ttdpCstTable 1 }


          TtdpCstEntry::=
                SEQUENCE {
                     ttdpCstTableIdx
                          Unsigned32,
                     ttdpCstUuid
                          OCTET STRING,
                     ttdpCstOrientation
                          TtdpDirection,
                     ttdpCstCnCnt
                          Unsigned32,
                     ttdpCstEtbnCnt
                          Unsigned32
                 }

          -- 1.0.61375.2.5.1.5.7.1.1
          ttdpCstTableIdx OBJECT-TYPE
                SYNTAX Unsigned32 (1..32)
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "Consist number (index in Consist table).

                     Consist nb 1 is the reference at extremity 1 of the train with
lowest CstUUID."
                ::= { ttdpCstEntry 1 }


          -- 1.0.61375.2.5.1.5.7.1.2
          ttdpCstUuid OBJECT-TYPE
                SYNTAX OCTET STRING (SIZE (16))
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "Consist UUID (Universally Unique IDentifier)."
                ::= { ttdpCstEntry 2 }


          -- 1.0.61375.2.5.1.5.7.1.3
          ttdpCstOrientation OBJECT-TYPE
                SYNTAX TtdpDirection
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "Orientation  of  the  Consist  in  relation  to  train  reference
direction."
                ::= { ttdpCstEntry 3 }


          -- 1.0.61375.2.5.1.5.7.1.4
          ttdpCstCnCnt OBJECT-TYPE
                SYNTAX Unsigned32 (0..32)
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "Number of CN in Consist."
                ::= { ttdpCstEntry 4 }
```

```
-- 1.0.61375.2.5.1.5.7.1.5
ttdpCstEtbnCnt OBJECT-TYPE
      SYNTAX Unsigned32 (0..32)
      MAX-ACCESS read-only
      STATUS current
      DESCRIPTION
            "Number of ETBN in Consist."
      ::= { ttdpCstEntry 5 }


-- 1.0.61375.2.5.1.5.8
ttdpCstCnTable OBJECT-TYPE
      SYNTAX SEQUENCE OF TtdpCstCnEntry
      MAX-ACCESS not-accessible
      STATUS current
      DESCRIPTION
            "List of CN in this Consist."
      ::= { ttdpTopoInfo 8 }


-- 1.0.61375.2.5.1.5.8.1
ttdpCstCnEntry OBJECT-TYPE
      SYNTAX TtdpCstCnEntry
      MAX-ACCESS not-accessible
      STATUS current
      DESCRIPTION
            "Entry for list of Consist CNs.

            ttdpCstTableIdx is the first level index in ttdpCstTable,
            ttdpCstCnTableIdx is the second level index in ttdpCstCnTable."
      INDEX { ttdpCstTableIdx, ttdpCstCnTableIdx }
      ::= { ttdpCstCnTable 1 }


TtdpCstCnEntry::=
      SEQUENCE {
            ttdpCstCnTableIdx
                  Unsigned32,
            ttdpCnType
                  INTEGER,
            ttdpCnId
                  Unsigned32,
            ttdpSubnetId
                  Unsigned32,
            ttdpSubnetIpAddr
                  IpAddress,
            ttdpSubnetIpMask
                  IpAddress
       }

-- 1.0.61375.2.5.1.5.8.1.1
ttdpCstCnTableIdx OBJECT-TYPE
      SYNTAX Unsigned32 (1..32)
      MAX-ACCESS read-only
      STATUS current
      DESCRIPTION
            "Index in this Consist CN table."
      ::= { ttdpCstCnEntry 1 }


-- 1.0.61375.2.5.1.5.8.1.2
ttdpCnType OBJECT-TYPE
      SYNTAX INTEGER
            {
            mvb(1),
            notUsed(2),
            can(3),
            ethernet(4)
            }
      MAX-ACCESS read-only
      STATUS current
      DESCRIPTION
            "CN type."
      ::= { ttdpCstCnEntry 2 }


-- 1.0.61375.2.5.1.5.8.1.3
```

```
        ttdpCnId OBJECT-TYPE
              SYNTAX Unsigned32 (1..32)
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "CN ID.

                    Statically defined, it identifies the Consist Network inside the
Consist"
              ::= { ttdpCstCnEntry 3 }


        -- 1.0.61375.2.5.1.5.8.1.4
        ttdpSubnetId OBJECT-TYPE
              SYNTAX Unsigned32 (1..63)
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "Used to number the CN subnet on ETB."
              ::= { ttdpCstCnEntry 4 }


        -- 1.0.61375.2.5.1.5.8.1.5
        ttdpSubnetIpAddr OBJECT-TYPE
              SYNTAX IpAddress
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "CN subnet IP address."
              ::= { ttdpCstCnEntry 5 }


        -- 1.0.61375.2.5.1.5.8.1.6
        ttdpSubnetIpMask OBJECT-TYPE
              SYNTAX IpAddress
              MAX-ACCESS read-only
              STATUS current
              DESCRIPTION
                    "CN subnet IP network mask."
              ::= { ttdpCstCnEntry 6 }


        -- 1.0.61375.2.5.1.5.9
        ttdpCnEtbnTable OBJECT-TYPE
              SYNTAX SEQUENCE OF TtdpCnEtbnEntry
              MAX-ACCESS not-accessible
              STATUS current
              DESCRIPTION
                    "List of ETBN connected to this CN."
              ::= { ttdpTopoInfo 9 }


        -- 1.0.61375.2.5.1.5.9.1
        ttdpCnEtbnEntry OBJECT-TYPE
              SYNTAX TtdpCnEtbnEntry
              MAX-ACCESS not-accessible
              STATUS current
              DESCRIPTION
                    "Entry for list of ETBN connected to this CN.

                    ttdpCstTableIdx is the first level index in ttdpCstTable,
                    ttdpCstCnTableIdx is the second level index in ttdpCstCnTable.
                    ttdpCnEtbnTableIdx is the third level index in ttdpCnEtbnTable."
              INDEX { ttdpCstTableIdx, ttdpCstCnTableIdx, ttdpCnEtbnTableIdx }
              ::= { ttdpCnEtbnTable 1 }


        TtdpCnEtbnEntry::=
              SEQUENCE {
                    ttdpCnEtbnTableIdx
                          Unsigned32,
                    ttdpCnEtbnId
                          Unsigned32
               }

        -- 1.0.61375.2.5.1.5.9.1.1
        ttdpCnEtbnTableIdx OBJECT-TYPE
              SYNTAX Unsigned32 (1..63)
```

```
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "Index in this CN ETBN table."
                ::= { ttdpCnEtbnEntry 1 }


           -- 1.0.61375.2.5.1.5.9.1.2
           ttdpCnEtbnId OBJECT-TYPE
                SYNTAX Unsigned32 (1..63)
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                     "Number of the ETBN (on ETB) connected to this CN."
                ::= { ttdpCnEtbnEntry 2 }


-- **********************************************************************
-- conformance statements
-- **********************************************************************
           -- 1.0.61375.2.5.2
           ttdpConformance OBJECT IDENTIFIER::= { ttdp 2 }


           -- 1.0.61375.2.5.2.2
           ttdpBasicGroup OBJECT-GROUP
                OBJECTS { ttdpVersion, ttdpSlowTimeout, ttdpFastTimeout, ttdpTopoTtl,
ttdpGlobalTopoTimeout,
                     ttdpLogicalLinksNb,      ttdpLogicalLinksIdx,      ttdpIsEndLink,
ttdpPortState, ttdpEtbId,
                     ttdpLocalEtbnMacAddr,     ttdpLocalEtbnId,     ttdpNodePosition,
ttdpIsAlone, ttdpConnTableValid,
                     ttdpEtbnCnt,  ttdpEtbnTableIdx,  ttdpEtbnId,  ttdpEtbnMacAddr,
ttdpEtbnOrientation,
                     ttdpEtbnIpAddr,       ttdpEtbnNodeRole,       ttdpEtbnInaugState,
ttdpEtbnInhibit, ttdpRemoteInhibit,
                     ttdpConnTableCrc32,          ttdpLengthen,             ttdpShorten,
ttdpConnectTableIdx, ttdpNeighbourMacAddr,
                     ttdpEtbnDirCnt,     ttdpEtbnVectorIdx,     ttdpEtbnVectorMacAddr,
ttdpCstCnt, ttdpCstTableIdx,
                     ttdpCstUuid,  ttdpCstOrientation,  ttdpCstCnCnt,  ttdpCstEtbnCnt,
ttdpCstCnTableIdx,
                     ttdpCnType,     ttdpCnId,     ttdpSubnetId,     ttdpSubnetIpAddr,
ttdpSubnetIpMask,
                     ttdpCnEtbnTableIdx,       ttdpCnEtbnId,       ttdpEtbTopoCntValid,
ttdpEtbTopoCnt, ttdpConfiguredPhysLinesNb,
                     ttdpActivePhysLinesNb,   ttdpPhysicalLinesIdx,   ttdpPeerLineId,
ttdpLineRcvState }
                STATUS current
                DESCRIPTION
                     "Mandatory parameters which are to monitor
                     the status of TTDP on an ETBN."
                ::= { ttdpConformance 2 }


           -- 1.0.61375.2.5.2.3
           ttdpStatsGroup OBJECT-GROUP
                OBJECTS      {      ttdpHelloSentFrames,      ttdpHelloReceivedFrames,
ttdpRemoteFastModeCnt, ttdpLocalFastModeCnt, ttdpTopoSentFrames,
                     ttdpTopoReceivedFrames }
                STATUS current
                DESCRIPTION
                     "Parameters which are optional to monitor
                     the status of TTDP on an ETBN (statistics)."
                ::= { ttdpConformance 3 }


           -- 1.0.61375.2.5.2.4
           ttdpBasicCompliance MODULE-COMPLIANCE
                STATUS current
                DESCRIPTION
                     "Basic implementation requirements for TTDP monitoring support.
                     The agent shall support the monitoring of mandatory parameters."
                MODULE -- this module
                     MANDATORY-GROUPS { ttdpBasicGroup }
                ::= { ttdpConformance 4 }
```

```
          -- 1.0.61375.2.5.2.5
          ttdpStatsCompliance MODULE-COMPLIANCE
               STATUS current
               DESCRIPTION
                    "Optional   implementation   requirements   for   TTDP   monitoring
support.
                    The agent shall support the monitoring of statistics parameters."
               MODULE -- this module
                    MANDATORY-GROUPS { ttdpStatsGroup }
               ::= { ttdpConformance 5 }



     END

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--
```

Bibliography

The table below summarizes IETF Request For Comments (RFC) used in this standard.

RFC references

Reference	Subject	Source
IETF RFC 768	User Datagram Protocol (UDP)	http://datatracker.ietf.org/doc/rfc768/
IETF RFC 791	Internet Protocol (IP)	http://datatracker.ietf.org/doc/rfc791/
IETF RFC 792	Internet Control Message Protocol (ICMP)	http://datatracker.ietf.org/doc/rfc792/
IETF RFC 793	Transmission Control Protocol (TCP)	http://datatracker.ietf.org/doc/rfc793/
IETF RFC 826	Ethernet Address Resolution Protocol (ARP)	http://datatracker.ietf.org/doc/rfc826/
IETF RFC 1033	Domain administrators operations guide	http://datatracker.ietf.org/doc/rfc1033/
IETF RFC 1035	Domain names – implementation and specification	http://datatracker.ietf.org/doc/rfc1035/
IETF RFC 1178	Choosing a name for your computer	http://datatracker.ietf.org/doc/rfc1178/
IETF RFC 1213	Management Information Base for Network Management of TCP/IP-based internets:MIB-II	http://datatracker.ietf.org/doc/rfc1213/
IETF RFC 1519	Classless Inter-Domain Routing (CIDR): an Address Assignment and Aggregation Strategy	http://datatracker.ietf.org/doc/rfc1519/
IETF RFC 1597	Address Allocation for Private Internets	http://datatracker.ietf.org/doc/rfc1597/
IETF RFC 1901	Introduction to Community-based SNMPv2	http://datatracker.ietf.org/doc/rfc1901/
IETF RFC 1905	Protocol Operations for Version 2 of the Simple Network Management Protocol (SNMPv2)	http://datatracker.ietf.org/doc/rfc1905/
IETF RFC 1906	Transport Mappings for Version 2 of the Simple Network Management Protocol (SNMPv2)	http://datatracker.ietf.org/doc/rfc1906/
IETF RFC 2236	Internet Group Management Protocol, Version 2 (IGMP)	http://datatracker.ietf.org/doc/rfc2236/
IETF RFC 2544	Benchmarking Methodology for Network Interconnect Devices	http://datatracker.ietf.org/doc/rfc2544/
IETF RFC 2365	Administratively Scoped IP Multicast	http://datatracker.ietf.org/doc/rfc2365/
IETF RFC 2474	Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers	http://datatracker.ietf.org/doc/rfc2474/
IETF RFC 2787	Definitions of Managed Objects for the Virtual Router Redundancy Protocol	http://datatracker.ietf.org/doc/rfc2787/
IETF RFC 2863	The Interfaces Group MIB	http://datatracker.ietf.org/doc/rfc2863/
IETF RFC 3046	DHCP Relay Agent Information Option	http://datatracker.ietf.org/doc/rfc3046/
IETF RFC 4122	A Universally Unique IDentifier (UUID) URN Namespace	http://datatracker.ietf.org/doc/rfc4122/

Other references

IEC 60571, *Railway applications – Electronic equipment used on rolling stock*

IEC 61375-2-1:2012, *Electronic railway equipment – Train communication network (TCN) – Part 2-1: Wire Train Bus (WTB)*

IEC 61784-2, *Industrial communication networks – Profiles – Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC 8802-3*

IEC 61918, *Industrial communication networks – Installation of communication networks in industrial premises*

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