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Electronic railway equipment — Train communication network (TCN)

Part 1: General architecture

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National foreword

This British Standard is the UK implementation of EN 61375-1:2012. It is identical to IEC 61375-1:2012.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
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Foreword

The text of document 9/1641/FDIS, future edition 3 of IEC 61375-1, 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 61375-1:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2013-04-26
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-07-26

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This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For the relationship with EU Directive(s) see informative Annex ZZ, which is an integral part of this document.

Endorsement notice

The text of the International Standard IEC 61375-1:2012 was approved by CENELEC as a European Standard without any modification.

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

IEC 61375-2-1	NOTE Harmonized as EN 61375-2-1.
IEC 61375-3-1	NOTE Harmonized as EN 61375-3-1.

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 When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
ISO/IEC 7498-1	-	Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model	-	-
ISO/IEC 8824-1	2002	Information technology - Abstract Syntax Notation One (ASN.1): Specification of basic notation	-	-
ISO/IEC 9646-1	1994	Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 1: General concepts	-	-
ISO/IEC 19501	2005	Information technology - Open Distributed Processing - Unified Modeling Language (UML)	-	-
UIC CODE 556	-	Information transmission in the train (train-bus)	-	-

Annex ZZ
(informative)

Coverage of Essential Requirements of EU Directives

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 EU Directive 2008/57/EC.

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directive concerned.

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

CONTENTS

INTRODUCTION

IEC 61375-1 defines the general architecture of the Train Communication Network (TCN) so as to achieve compatibility between consist networks defined by this part of IEC 61375 and train backbones defined by this part of IEC 61375.

The TCN has a hierarchical structure with two levels of networks, a train backbone and a consist network:

a) for interconnecting vehicles in close or open trains, this part of IEC 61375 specifies train backbones with different characteristics;
b) for connecting standard on-board equipment, this part of IEC 61375 specifies consist networks with different characteristics.

The general architecture of the TCN, which is defined in this part of the standard, shall

c) establish the rules for interconnecting consist networks with train backbones, as
   - identifying the interfaces;
   - defining the principles of how train topology changes can be discovered;
   - defining the basic communication services provided by train backbones to be used by consist networks;
d) establish basic rules for the train backbone and for the consist network;
e) establish rules for communalities in operation, as:
   - patterns for the communication between users;
   - addressing principles;
   - data classes to be supported.

ELECTRONIC RAILWAY EQUIPMENT – TRAIN COMMUNICATION NETWORK (TCN) –

Part 1: General architecture

1 Scope

This part of IEC 61375 applies to the architecture of data communication systems in open trains, i.e. it covers the architecture of a communication system for the data communication between vehicles of the said open trains, the data communication within the vehicles and the data communication from train to the ground.

The applicability of this part of IEC 61375 to the train network technologies allows for interoperability of individual vehicles within open trains in international traffic. The data communication systems inside vehicles are given as recommended solutions to cope with the said TCN. In any case, proof of compatibility between a proposed train backbone and a proposed consist network will have to be brought by the supplier.

This part of IEC 61375 may be additionally applicable to closed trains and multiple unit trains when so agreed between purchaser and supplier.

NOTE 1 For a definition of open trains, multiple unit trains and closed trains, see Clause 3.

NOTE 2 Road vehicles such as buses and trolley buses are not considered in this part of IEC 61375.

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.

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

ISO/IEC 8824-1:2002, *Information technology – Abstract Syntax Notation One (ASN.1): specification of basic notation*

ISO/IEC 9646-1:1994, *Information technology – Open Systems Interconnection – Conformance testing methodology and framework – Part 1: General concepts*

ISO/IEC 19501:2005, *Information technology – Open Distributed Processing – Unified Modeling Language (UML) Version 1.4.2*

UIC CODE 556, *Information transmission in the train (train-bus)*

3 Terms, definitions, abbreviated terms, acronyms, and conventions

3.1 Terms and definitions

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

3.1.1
active train backbone node
train backbone node receiving a sequence number during inauguration and forwarding user data packets between consist network and train backbone

3.1.2
application layer
upper layer in the OSI model, interfacing directly to the Application

3.1.3
application layer interface
definition of the services offered by the application layer

3.1.4
application process
an element within a real open system which performs the information processing for a particular application

3.1.5
bridge
device which stores and forwards frames from one bus to another on the base of their link layer addresses

3.1.6
broadcast
nearly simultaneous transmission of the same information to several destinations. Broadcast in the TCN is not considered reliable, i.e. some destinations may receive the information and others not

3.1.7
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

3.1.8
closed train
train composed of one or a set of consists, where the composition does not change during normal operation, for instance metro, sub-urban train, or high speed train units

EXAMPLE Consists are coupled in a workshop to establish a closed train for operation.

3.1.9
communication devices
devices connected to consist network or train backbone with the ability to transport, source or sink data

3.1.10
composition
number and characteristics of the vehicles forming a train

3.1.11
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

3.1.12
consist
train set
rake of coaches
single vehicle or a group of vehicles which are not separated during normal operation, and which contains no, one or several consist networks

EXAMPLE The vehicles of a consist are steadily connected in a workshop, and automatic couplers are mounted at both ends of the consist to facilitate the coupling and de-coupling of complete consists in the workshop or during operation.

3.1.13
consist network
communication network interconnecting communication devices in one consist

NOTE Consist networks do not spread beyond consist boundaries.

3.1.14
consist network address
network address, which does not change after inauguration and which is used to address communication device in the own consist network

3.1.15
consist sequence number
sequence number of the consist in the train as obtained during train inauguration

3.1.16
consist switch
consist network node
network component used in consist network based on switched technology (ECN). See “switch” 3.1.58.

3.1.17
consumer
receiver of a message at the transport layer (see: “producer” 3.1.47)

3.1.18
destination device
receiver of a data packet (see: “source device” 3.1.55)

3.1.19
end device
unit connected to one consist network or to one set of consist networks prepared for redundancy reasons

3.1.20
end node
node which terminates the train backbone

3.1.21
function
application process which exchanges messages with another application process

3.1.22
gateway
connection between different communication technologies

3.1.23
group address
address of a multicast group to which a device belongs

3.1.24
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

3.1.25
integrity
property of a system to recognize and to reject wrong data in case of malfunction of its parts

3.1.26
intermediate node
node which establishes continuity between two bus sections connected to it, but does not terminate them

3.1.27
jumper cable
cable connecting the trunk cables of two consecutive vehicles, possibly of a larger cross-section than the trunk cable, and which is plugged by hand in the case of the UIC-cable. There are generally two jumper cables between vehicles

3.1.28
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)

[IEC 61784-2]

3.1.29
local area network
part of a network characterized by a common medium access and address space

3.1.30
medium access control
sublayer of the link layer, which controls the access to the medium (arbitration, mastership transfer, polling)

3.1.31
medium
physical carrier of the signal: electrical wires, optical fibers, etc.

3.1.32
message
data item transmitted in one or several packets

3.1.33
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.

3.1.34
multicast
transmission of the same message to a group of receivers, identified by their group address; the word "multicast" is used even if the group includes all receivers

3.1.35
multiple unit train
a train consisting of a set of closed trains, where the composition of the set may change during normal operation

3.1.36
network
set of possibly different communication systems which interchange information in a commonly agreed way

3.1.37
network address
address which identifies a communication device on network layer

3.1.38
network device
components used to set up consist networks and train networks. These may be passive components like cables or connectors, active unmanaged components like repeaters, media converters or (unmanaged) switches, or managed active components like gateways, routers and (managed) switches.

3.1.39
network layer
layer in the OSI model responsible for routing between different busses

3.1.40
network management
operations necessary to remotely configure, monitor, diagnose and maintain the network

3.1.41
node
device on the train backbone, which may act as a gateway between train backbone and consist network

3.1.42
octet
byte
8-bit word stored in memory or transmitted as a unit

3.1.43
open train
train composed of one or a set of consists, where the configuration may change during operation, as for instance locomotive hauled international UIC trains

3.1.44
operator
enterprise or organization which is operating trains

3.1.45
packet
unit of a message (information, acknowledgement or control) transmitted by protocols on network or transport layer

3.1.46
passive train backbone node
train backbone node which is in standby to an active train backbone node in a consist network

3.1.47
producer
sender of a message at the transport layer (see: “consumer” 3.1.17)

3.1.48
publisher
source of a dataset for broadcasting (see: “subscriber” 3.1.57)

3.1.49
receiver
electronic device which may receive signals from the physical medium

3.1.50
repeater
connection at the physical layer between bus segments, providing an extension of the bus beyond the limits permitted by passive means. 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

3.1.51
residual error rate
probability of integrity breach (unrecognized wrong bit) per transmitted bit

3.1.52
ring topology
active network where each node is connected in series to two other nodes

[IEC 61918]

NOTE Ring may also be referred to as loop.

3.1.53
router
connection between two busses at the network layer, which forwards datagrams from one bus to another on the base of their network address

3.1.54
service
capabilities and features of a sub-system (e.g. a communication layer) provided to a user

3.1.55
source device
sender of a data packet (see: “destination device” 3.1.18)

3.1.56
sporadic data
transmission of data on a demand basis

3.1.57
subscriber
one of the sinks of a broadcast dataset (see: “publisher” 3.1.48)

3.1.58
switch
MAC bridge as defined in IEEE 802.1D

3.1.59
topography
data structure describing the nodes attached to the train backbone, including their address, orientation, position and node descriptor

3.1.60
topology
possible cable interconnection and number of devices in a given network

3.1.61
topography counter
counter in a node which is incremented at each new inauguration

3.1.62
train
composition of one or a set of consists, which can be operated as an autonomous unit, e.g. containing drives and at least one driver's cab. Trains can be categorized into open trains (see 3.1.43), closed trains (see 3.1.8) and multiple unit trains (see 3.1.35).

3.1.63
train communication network
data communication network for connecting programmable electronic equipment on-board rail vehicles

3.1.64
train backbone
bus connecting the vehicles of a train and which conforms to the TCN protocols

3.1.65
train backbone node
node
device connected to the train backbone. A train backbone node can be used to connect end devices or consist networks to the train backbone. A train backbone node can be active (see 3.1.1) or passive (see 3.1.46).

3.1.66
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.

3.1.67
train network address
dynamic network address, which is used to address communication devices in other consist networks. This address can change after each inauguration.

3.1.68
train network management
services of the network management for TCN

3.1.69
transport layer
layer of the OSI model responsible for end-to-end flow control and error recovery

3.2 Abbreviations and acronyms

ANSI	American National Standard Institute, a standardisation body in the United States
ALG	Application Layer Gateway
BER	Bit Error Rate, the rate of bit errors in a data stream, mainly caused by noise (random bit errors), but also caused by memory defects in data storing devices (systematic bit errors).
BR	Bit Rate, the rate of data throughput on the medium expressed in bits per second (bit/s) or in hertz (Hz), whichever is appropriate
CAN	Controller Area Network
CN	Consist Network
CPS	Communication Protocol Stack
CRC	Cyclic Redundancy Check, a data integrity check based on polynomial division
DIN	Deutsches Institut für Normung, the German national standardisation body
ECN	Ethernet Consist Network
ED	End Device
EIA	Electronics Industries Association, a standardisation body in the United States
ETB	Ethernet Train Backbone
IEC	International Electrotechnical Commission, Geneva
IEEE	Institute of Electrical and Electronics Engineers, New York
IETF	Internet Engineering Task Force
IP	Internet Protocols, as defined by the IETF
ISO	International Standard Organisation, Geneva
ITU	International Telecommunication Union, the international standardisation body for telecommunications based in Geneva
MAC	Medium Access Control, a sub-layer within the Link Layer ruling which device is entitled to send on the bus
MCG	Mobile Communication Gateway
MTU	Mobile Train Unit
MVB	Multifunction Vehicle Bus
ND	Network Device
OSI	Open System Interconnection, a universal communication model defined in ISO/IEC 7498-1
PCTR	Protocol Conformance Test Report, defined in ISO/IEC 9646-1
PICS	Protocol Implementation Conformance Statement, defined in ISO/IEC 9646-1
RFC	Request For Comments, Internet Standard published by the IETF
TB	Train Backbone
TBN	Train Backbone Node
TCN	Train Communication Network, a set of communicating vehicle and Train Backbones
UIC	International Union of Railways, the international railways operators association
URI	Uniform Resource Identifier, as defined by the IETF
UML	Unified Modeling Language, defined in ISO/IEC 19501.
WTB	Wire Train Bus

3.3 Conventions

3.3.1 Requirement conventions

Shall is used to describe requirements.

Should is used to describe recommendations.

May is used to describe acceptable features.

Could is used to describe possible ways.

3.3.2 Base of numeric values

This part of IEC 61375 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 8824-1) convention.

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

3.3.3 Naming conventions

If the keyword name is composed, the different parts of the name are united with a space.

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 are beginning with a capital letter.

EXAMPLE “NumberOfConsists“

Function names are written with a lower case letter at the beginning.

If the function name is composed, the different parts of the name are united without a space, and all parts except the first part are beginning with a capital letter.

EXAMPLE “indicateTopoChange“

3.3.4 State diagram conventions

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

4 Basic architecture

4.1 Contents of this clause

This clause specifies the hierarchical network architecture of the train communication network together with the main characteristics of its parts and the interfaces in between.

4.2 General

4.2.1 Technology classes

This part of IEC 61375 defines a set of network technologies which can be used, either solely or in combination, to set up the train communication network. These network technologies can be classified in two technology classes: either the bus technology class (WTB, MVB, CANopen) or the switched technology class (ETB, ECN). The bus technology class is characterized by having multiple end devices connected to the same data transmission media, forming one broadcast and one collision domain. In the switched technology class is one end device connected to a switch, which is responsible to actively forward user data inside the network. A switched technology based network has the possibility to restrict broadcast and collision domains.

4.2.2 Component types

The TCN is set up by two types of communication devices: network devices (ND) and end devices (ED). Network devices are all those devices whose primary use is to transport and forward user data. Examples of network devices are passive components like cables and connectors or active components like repeaters, bridges, switches, routers or application layer gateways. End devices on the other hand provide typically the sources and sinks of user data. Examples of end devices are controllers, displays or sub-systems.

NOTE There might also be devices which provide both functions of network devices and functions of end devices, e.g. network devices providing diagnostic information or network topology information. These devices are sometimes called “hybrid” devices. The main determination of a device should define whether it is referred to as network device or end device.

4.3 Hierarchical structure

4.3.1 Network levels

This part of IEC 61375 defines the architecture of the TCN as a hierarchy of two network levels, a train backbone level and a consist network level, as shown in Figure 1.

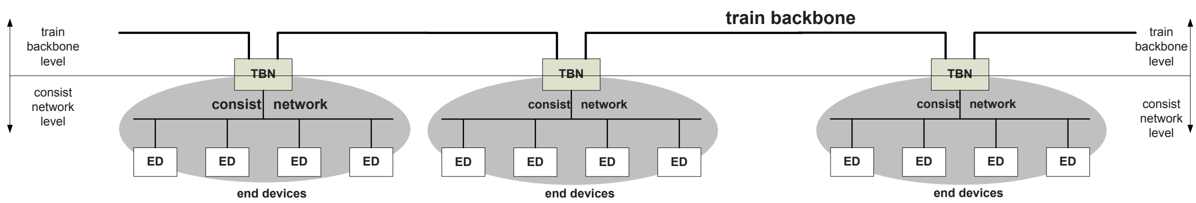

Figure 1 – Train backbone and consist network

The communication between consist networks shall be only possible over the train backbone.

NOTE This two level architecture has been selected for the following reasons:

– The communication network which is set-up by the consist network is a static, preconfigured network. In opposite to that is the communication network, which is set-up by the train backbone, a dynamic network, which changes its topology each time there is a change in the train composition. Communication between train backbone nodes may be interrupted if a reconfiguration of the train backbone happens. During times of unavailability of the train backbone communication the consist network communication shall not be affected.

– A break-down of a consist network shall not (e.g. due to power loss in the consist) compromise the communication between other consists of the same train.

– The train backbone cannot be loaded with all the data traffic in a train, therefore intra-consist data shall be kept local to the consist. Only data traffic directed to other consists shall be transported over the train backbone.

4.3.2 Train backbone level

On train backbone level, the train backbone interconnects the train backbone nodes (TBN) which are located in the consists constituting the train.

Each consist could have 0, 1 or more train backbone nodes.

A more detailed specification of the train backbone is given in Clause 5.

4.3.3 Consist network level

On consist network level, the consist networks interconnect end devices which are located in one consist. A consist may contain no, one or several consist networks as depicted in Figure 2 as an example of a consist with two consist networks.

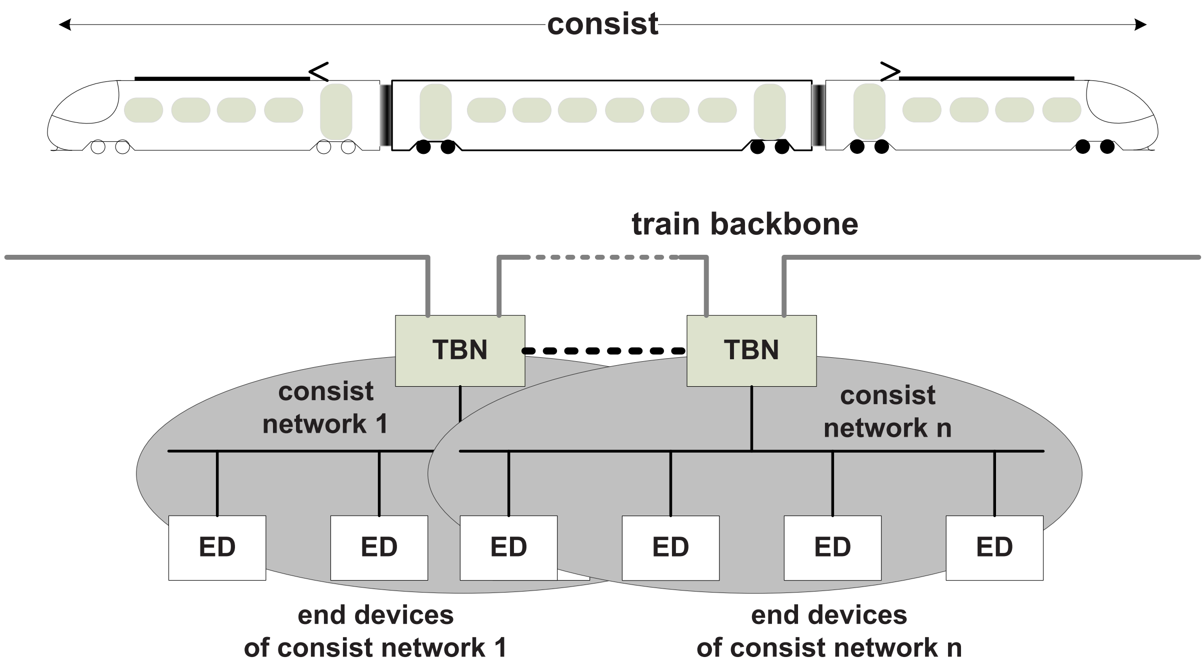

Figure 2 – Consist with two consist networks

A specific end device shall be connected to one consist network. A specific end device could be connected to a set of consist networks in case of consist network redundancy (see 4.3.4).

NOTE End Devices could connect to multiple consist networks via different interfaces on the device. One physical device can contain logically two or more end devices in it.

The consist networks in a consist shall be identified by a consecutive consist network number with start value = 1.

EXAMPLE The consist in Figure 2 contains two consist networks with number 1 and number 2.

If the consist belongs to a closed train, the consist networks in the closed train shall be identified by an consecutive closed train network number with start value = 1.

EXAMPLE In a closed train composed of two consists with each containing two consist networks are the consist networks numbered from 1 to 2 in each consist, and from 1 to 4 in the closed train.

A more detailed specification of the consist network is given in Clause 6.

4.3.4 Interface between train backbone and consist network

A consist network shall be connected to the train backbone via one or more train backbone node(s).

NOTE 1 Consist networks belonging to the same consist may be connected to the same train backbone node(s).

A train backbone node may be:

– active. in this case it shall forward user data packets between the consist network and the train backbone;

– passive. in this case it shall not forward user data packets between the consist network and the train backbone.

The connection between consist network and train backbone should be redundant. The following architectures for redundancy could be used:

– Consist network redundancy. Here the complete consist network is duplicated for redundancy. The train backbone node(s) of the redundant consist network(s) could be passive.
– Train backbone node redundancy. Here, the consist network and the train backbone are connected by at least two train backbone nodes, with at least one being active.

NOTE 2 Consist network redundancy can for instance be used for ladder type consist network topologies.

NOTE 3 Train backbone node redundancy with one active train backbone node is for instance used in UIC trains equipped with WTB.

NOTE 4 Multiple active train backbone nodes between consist network and train backbone can all be used for forwarding user data packets between consist network and train backbone (load balancing).

The train backbone node shall provide a gateway function which, as defined in 6.4, rules the user data packet transfer between the consist network and the train backbone.

4.3.5 End devices connected to train backbone

It should be possible to connect end devices directly to the train backbone via a train backbone node as it is depicted in Figure 3, showing an example of connecting two end devices and one consist network to the train backbone.

NOTE Addressing of end devices connected to the train backbone will differ from addressing end devices connected to the consist network, see 7.3.2.2.

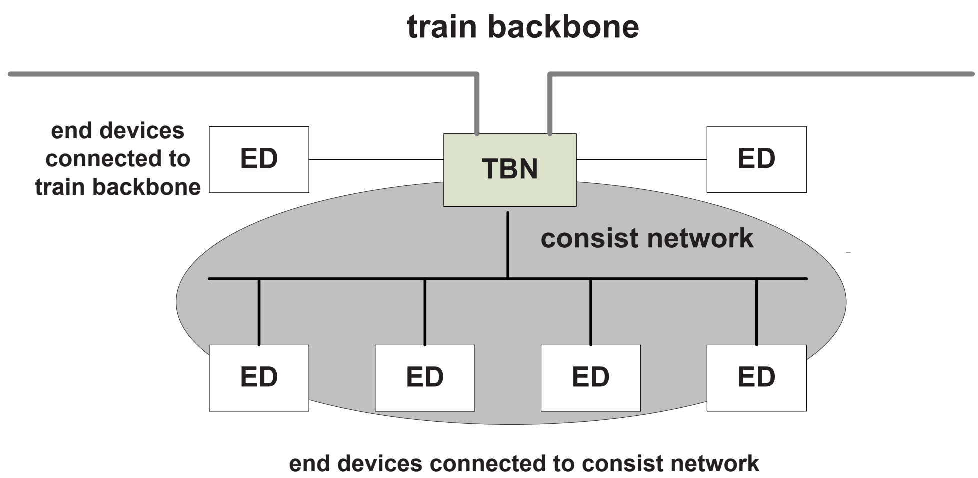

Figure 3 – End device connected to the train backbone (example)

4.4 Network configurations

Both train backbone and consist network may be implemented by one or a combination of the network technologies which are specified in this part of IEC 61375.

The network technologies defined in this part of IEC 61375 can be used in following configurations:

For train backbone:

a) A train may use either WTB or ETB.

b) A train may use WTB and ETB in parallel.

EXAMPLE WTB is used for operational data and ETB for multimedia data.

c) A train may use multiple ETB in parallel.

EXAMPLE One ETB is used for operational data and another ETB for multimedia data.

d) Trains with static configuration (no operational connection or disconnections of train sets) may omit the train backbone.

NOTE Train Backbones of different technology (e.g. WTB and ETB) may be connected by the mean of a gateway.

For consist network:

e) Any of the consist network technologies MVB, CAN or ECN may be used in a consist.

f) A combination of consist network technologies MVB, CAN or ECN may be used in a consist, if explicitly supported by the involved technologies. In this case data exchange between the consist network technologies and between consist network and train backbone need to be specified.

g) Simple consists need not have a consist network at all. End devices may be connected directly to the train backbone node, or the train backbone node implements functionalities of end devices.

4.5 Train to ground connection (option)

Train to ground connection from the onboard network to a ground network shall be provided by mobile communication gateways (MCG). A MCG shall provide at least two interfaces, one to the onboard network and one to the ground network.

Each consist should provide at least one MCG with a permanent or temporary, static or roaming connection to a ground consist gateway (GCG). There may however be simple consists without a MCG. The GCG shall provide a consist ground interface serving as the consist access point for the train to ground communication as illustrated in Figure 4. The consist ground interface shall abstract from the technology which is used for the GCG to MCG connection.

NOTE 1 A preferable solution is to provide a static address of the consist at the consist ground interface.

NOTE 2 The ground networks might be interconnected, e.g. by the public internet.

Besides providing communication access to the associated consist network, the MCG/GCG should also provide communication access to other consist networks in the train.

NOTE 3 Two use cases must be distinguished:

a) Accessing a specific consist from ground without knowing in which train this consist is presently running.

b) Accessing a known train from ground.

The MCG could be connected to the consist network or directly to a train backbone node.

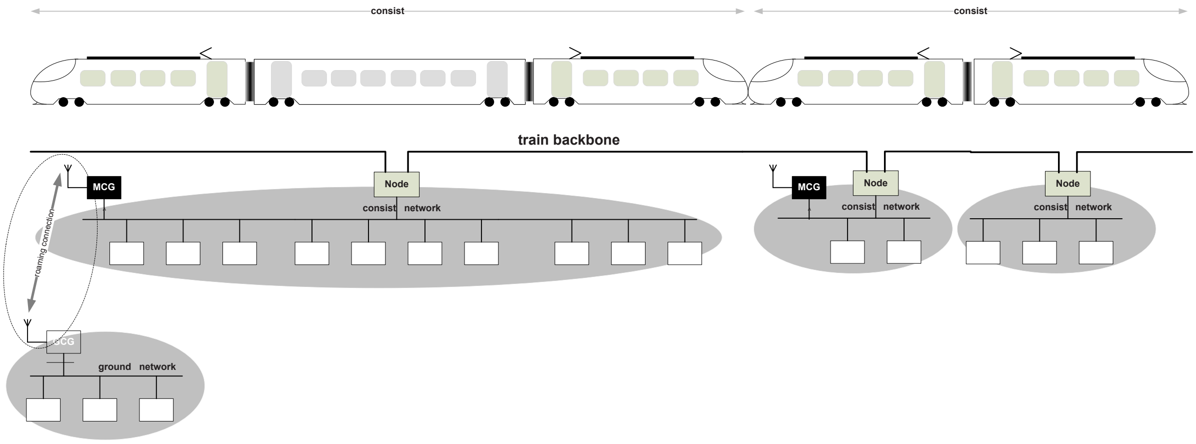

Figure 4 – Communication between train and ground (example)

EXAMPLE The consist shown on the right side in Figure 4 is composed of two consist networks, the second consist network without MCG. These consist networks shall be remotely accessible by at least the MCG connected to the first consist network of the same consist. Preferred is however a solution where all consists are accessible from either MCG.

5 Train backbone

5.1 Contents of this clause

This clause specifies the basic features a train backbone has to provide to ensure train wide communication in all types of trains. These features shall be common to all the train backbone technologies defined in this part of IEC 61375. As the train backbone interconnects the train backbone nodes in a train, which themselves belong to specific consists and vehicles in the train, it is first necessary to list possible train compositions ("topologies") and to define directions and orientation on vehicle, consist, closed train and train level. Then the discovery of the actual train composition, called "train inauguration", is described, and finally the services of train backbone operation are defined.

5.2 Train backbone topology

5.2.1 General

This part of IEC 61375 defines the data communication interface between consists as the connection of train backbone nodes, located in consists, to a train backbone, as shown in Figure 5.

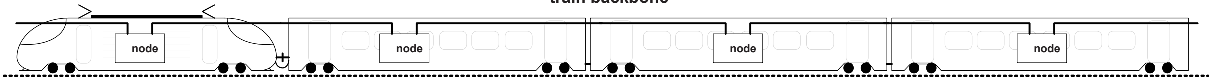

Figure 5 – Interfaces between consists

NOTE 1 Train backbone nodes of different technology classes (WTB and ETB) cannot be connected to the same train backbone.

NOTE 2 It may be possible to connect two train backbones of different technology class by the mean of a gateway, see also 6.4.

5.2.2 Train backbone based on bus technology

When a bus technology is used, nodes shall be connected to a common data transmission medium, as shown in Figure 6, which establishes a common broadcast and a common collision domain.

In order to avoid collisions, a method shall be defined which controls bus access.

To support redundancy, the common data transmission medium should be doubled.

For supporting train inauguration, nodes shall be able to interrupt the bus and to receive transmitted data direction selective.

A mechanism shall be provided which prevents that a powerless or not operating node interrupts the bus unintended.

NOTE A bypass relay can be used to bridge a node if the node is powerless or not operating.

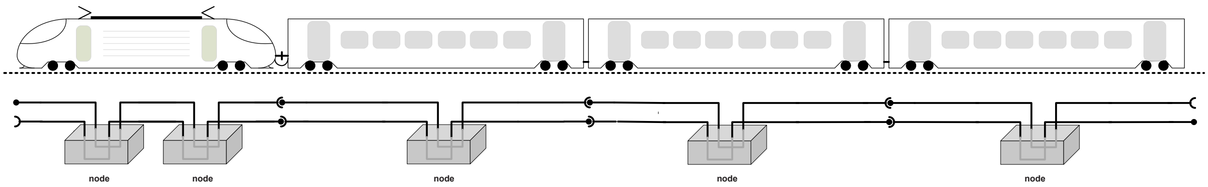

Figure 6 – Train backbone bus topology

5.2.3 Train backbone based on switched technology

When a switched technology is used, nodes shall provide a data transmission medium to each of their direct neighbour nodes, if present, as shown in Figure 7.

To support redundancy, the data transmission medium should be doubled.

A mechanism shall be provided which prevents that a powerless or not operating node interrupts the bus unintended.

NOTE A bypass relay can be used to bridge a node if the node is powerless or not operating.

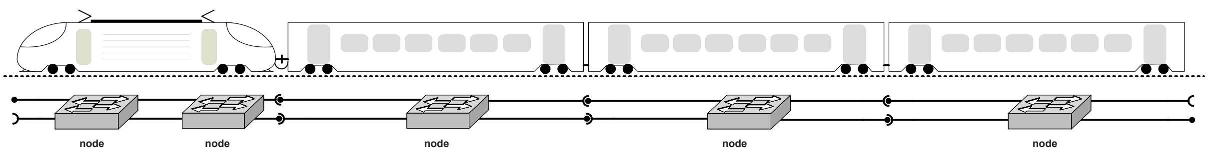

Figure 7 – Train backbone switched topology

5.3 Train compositions

The number and type of connected consists in a train can vary during operation, especially for the train operations listed in Table 1.

Table 1 – Train composition changes

Train operation	Description
Train lengthening	One or many consists are connected at one train end. A special case of lengthening is the coupling of two trains.
Train shortening	One or many consists are removed from the train at one train end. A special case of shortening is splitting one train into two trains
Insertion	An insertion takes place when a train backbone node, in the middle of the train, becomes activated later than its own neighbour nodes

5.4 Train backbone node numbering

All active train backbone nodes in a train shall be assigned a unique sequence number during train inauguration (see 5.6).

NOTE These sequence numbers may change after each train inauguration.

EXAMPLE WTB assigns numbers from 1..63 to WTB nodes, with WTB master node always having sequence number 1, WTB nodes on top of the WTB master node having numbers 63..33 and WTB nodes behind the WTB master node having numbers from 2 to 31.

5.5 Train directions

5.5.1 Vehicle

Directions and orientations of a vehicle are defined as follows:

a) One end of the vehicle is identified as Extremity 1, the other as Extremity 2.

b) Reference Direction_1 of a vehicle is directed towards Extremity 1, and Direction_2 is directed towards Extremity 2.

c) If Direction_1 points north, the side of the vehicle that points west is named side A, the side which points east is named side B.

d) A train backbone node uses the same conventions for A and B as the vehicle it is located in.

NOTE 1 The assignment of vehicle directions and orientations is static.

NOTE 2 Directions and orientations in a vehicle are shown in Figure 8.

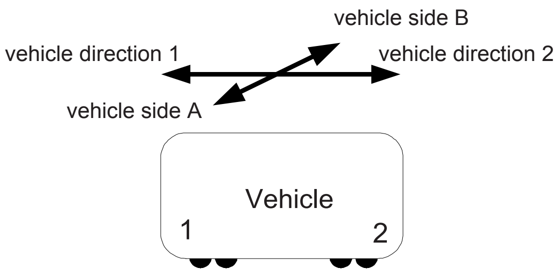

Figure 8 – Directions and orientation in a vehicle

5.5.2 Consist

Directions and orientations of a consist are defined as follows:

a) One end of the consist is identified as Extremity 1, the other as Extremity 2.

b) Reference Direction_1 of a consist is directed towards Extremity 1, and Direction_2 is directed towards Extremity 2.

c) If Direction_1 points north, the side of the consist that points west is named side A, the side which points east is named side B.

The directions of a vehicle inside a consist may be identical to the directions of the consist or opposite. In the latter case this vehicle is described as having “inverse” orientation with respect to the consist.

Vehicles in a consist shall be consecutively numbered with the first vehicle in direction 1 being vehicle number 1.

A single vehicle consist shall have identical directions as the vehicle it is composed of.

EXAMPLE Directions and orientations in a 5 vehicle consist can be as shown in Figure 9.

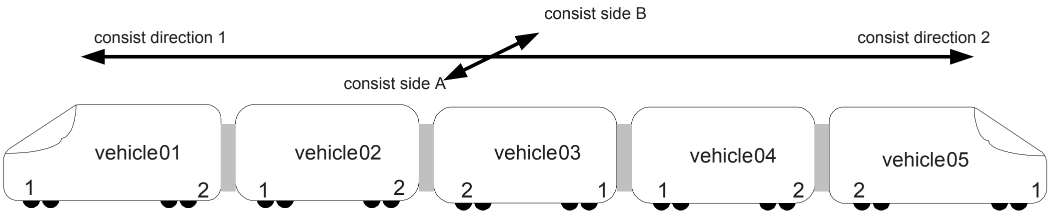

Figure 9 – Directions and orientations in a consist

NOTE As can be seen from Figure 9, the vehicles in a consist might not have the same orientation as the consist itself.

5.5.3 Closed train

Directions and orientations of a closed train are defined as follows:

a) One end of the closed train is identified as Extremity 1, the other as Extremity 2.

b) Reference Direction_1 of a closed train is directed towards Extremity 1, and Direction_2 is directed towards Extremity 2.

c) If Direction_1 points north, the side of the closed train that points west is named side A, the side which points east is named side B.

The directions of a Consist inside a closed train may be identical to the directions of the closed train or opposite. In the latter case this consist is described as having “inverse” orientation with respect to the closed train.

Consists in a closed train shall be consecutively numbered with the first consist in direction 1 being consist number 1.

EXAMPLE Directions and orientations in a closed train with 2 consists can be as shown in Figure 10.

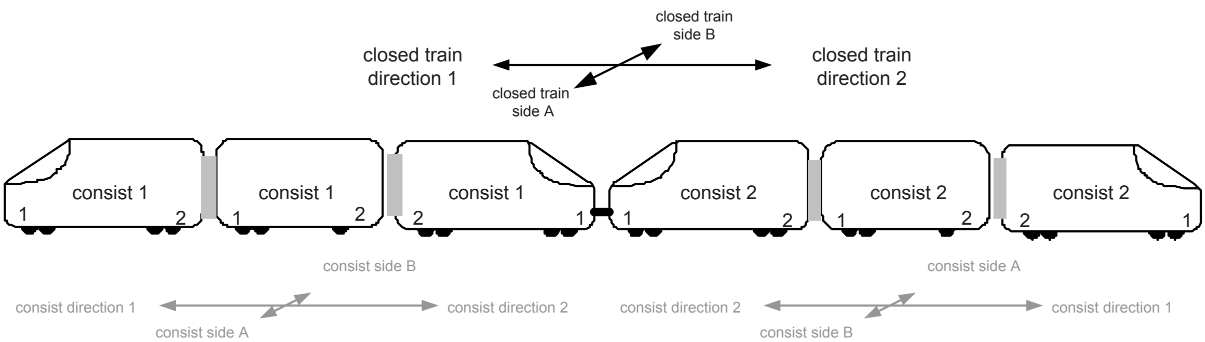

Figure 10 – Directions and orientations in a closed train

NOTE As can be seen from Figure 10, the consists in a closed train might not have the same orientation as the closed train itself.

5.5.4 Train

5.5.4.1 General

Trains can be dynamically composed; therefore the directions and orientations in a train may also change dynamically. There are basically two levels of directions and orientations defined:

- direction and orientation on communication network level (“TCN directions”)

- one or more directions and orientations on application level (“application directions”)

TCN directions and applications directions can change independently from each other.

5.5.4.2 TCN directions

TCN directions and orientations of a train are defined as follows:

a) One end of the train is identified as Extremity 1, the other as Extremity 2.

b) Reference Direction_1 of a train is directed towards Extremity 1, and Direction_2 is directed towards Extremity 2.

c) If Direction_1 points north, the side of the train that points west is named side A, the side which points east is named side B;

Which of the ends of a train is assigned Extremity 1 is defined by the train backbone technology.

EXAMPLE 1 For WTB, the TCN directions depend on the node position of the train backbone bus master.

EXAMPLE 2 Directions and orientations in a train can be as shown in Figure 11.

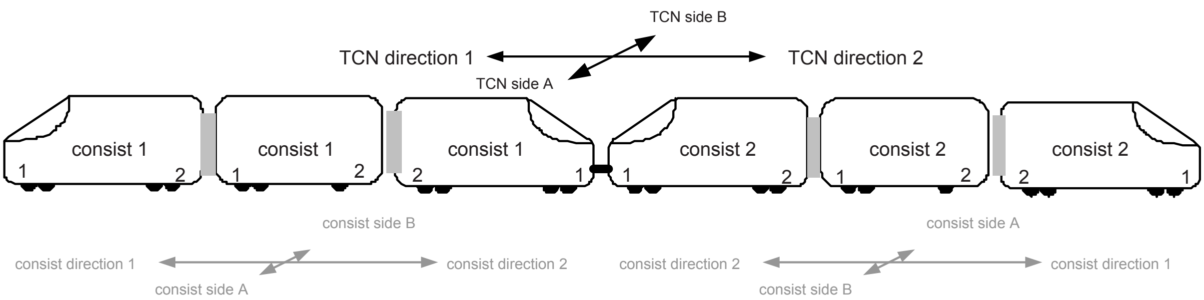

Figure 11 – Directions and orientations in train (TCN directions)

The direction/orientation of a consist inside a train may be identical to the direction/orientation of the train or opposite. In the latter case this consist is described as having “inverse” orientation with respect to the train.

EXAMPLE 3 Directions and orientations in a 2 consist open train can be as shown in Figure 11. Note that consist 2 direction is “inverse” with respect to the train orientation.

The direction/orientation of a closed train inside a multiple unit train may be identical to the direction/orientation of the multiple unit train or opposite. In the latter case this closed train is described as having “inverse” orientation with respect to the multiple unit train.

Consists in a train are consecutively numbered with the first consist in TCN direction 1 being the consist number 1.

Closed trains in a multiple unit train are consecutively numbered with the first closed train in TCN direction 1 being the closed train number 1.

5.5.4.3 Application directions

Application directions shall be defined in the communication and application profiles of TCN.

NOTE The communication and application profiles are defined in other parts of the IEC 61375 series.

EXAMPLE For UIC, the train directions are specified in UIC 556 and depend on the position of the leading vehicle.

5.6 Train inauguration

5.6.1 Objectives

The train inauguration procedure shall determine the present sequence of all active train backbone nodes in a train and shall determine the present orientation of the consist, where a node is located in, with respect to the train orientation. This is referred to as the train topology.

The train inauguration protocol is executed in all active train backbone nodes. This protocol depends on the technology of the train backbone, e.g. WTB or ETB.

5.6.2 Train network directory

Each active train backbone node executing the train inauguration procedure shall prepare a train network directory which shall contain all the data about the actual train backbone topology and which should also contain user defined data which describe the properties and functions of the individual consists. The train network directory should be made available to all devices (network devices and end devices) interested.

As the content of the train network directory depends on the train backbone technology and on the related communication profile, this subclause specifies only the basic content of the train network directory.

The train network directory should be structured:

- one common part for train parameters
- a part for each consist network with closed train, consist and consist network specific parameters (“consist network directory”)
- a part for each vehicle with vehicle specific parameters (“vehicle directory”)
- optional: a part for each end device with device specific parameters (“device directory”)

EXAMPLE An example of a train network directory structure is given in Figure 12.

NOTE 1 A train network directory should also be prepared if the TBN is the only TBN connected to the train backbone. This means practically that there is a train with one consist.

The train network directory shall be versioned:

- a static version number for the train network directory data structure. This version number is referred to as “train network directory version”
- a dynamic version number which shall change each time there is a change in the content of the train network directory. This version number is referred to as “TopoCount”.

NOTE 2 It can be more optimal to provide two dynamic information versions, one which indicates topology changes and one which indicates only parameter changes without topology changes, because the latter case does typically not have impact on the train wide addressing.

A changed TopoCount shall not equal a previously assigned TopoCount unless it can be ensured that this previous TopoCount is no more used by any communication device.

In order to prevent that a receiver of train data refers to another version of the train network directory than the sender of the train data, one of the two following measures shall be implemented:

a) Communication devices which are using a wrong TopoCount while trying to send data train wide shall not be granted access to the train backbone.
b) Communication devices providing the data source shall inform the receiving communication devices about the train network directory version and the TopoCount which was used for the preparation for the data.

NOTE 3 For the WTB, this version information is referred to as “topo_count”.

EXAMPLE The train network directory could contain the parameters which are marked with recommended (R) or optional (O) in Table 2 to Table 5.

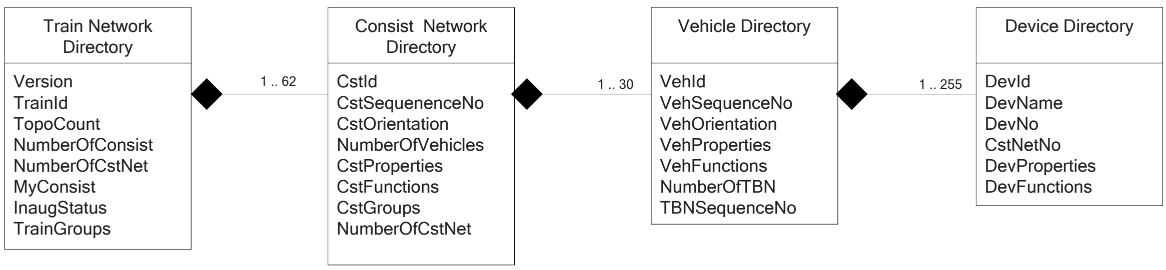

Figure 12 – Structure of train network directory (example)

Table 2 – Train network specific parameters (example)

Parameter	Recommended (R) Optional (O)	Description
Version	R	Version of the train network directory data structure
TrainId	O	Unique identifier of the train
TopoCount	R	Dynamic version of the train network directory content. Value changes with each new inauguration
NumberOfConsist	R	Number of consists in the train
NumberOfCstNet	R	Number of consist networks in the train
MyConsist	R	Consist sequence number of the local consist in the train as defined in 5.5.4.
InaugStatus	R	Inauguration status: INVALID UNCONFIRMED CONFIRMED
TrainGroups	O	List of train groups, see 7.3.2.3

Table 3 – Consist network specific parameters (example)

Parameter	Recommended (R) Optional (O)	Description
CstId	O	Unique consist identifier
CstSequenceNo	R	Consist sequence number in the train as defined in 5.5.4.
CstOrientation	R	Consist orientation with respect to the train orientation as defined in 5.5.4.
NumberOfVehicles	R	Number of vehicles in the consist
CstProperties	O	Consist properties, e.g. owner, operator, list of equipment, leading consist
CstFunctions	O	List of functions provided by the consist
CstGroups	O	List of consist groups, see 7.3.2.3
NumberOfCstNet	R	Overall number of consist networks in this consist

Table 4 – Vehicle specific parameters (example)

Parameter	Recommended (R) Optional (O)	Description
VehId	R	Unique vehicle identifier
VehSequenceNo	R	Vehicle sequence number in the consist (acc. to Figure 9)
VehOrientation	R	Vehicle orientation with respect to the consist orientation (acc. to Figure 9)
VehProperties	O	Static and dynamic vehicle properties
VehFunctions	O	List of functions provided by the vehicle
NumberOfTBN	R	Total number of train backbone nodes in this vehicle
TBNSequenceNo	R	Number of the train backbone node in this vehicle

Table 5 – Device specific parameters (example)

Parameter	Recommended (R) Optional (O)	Desription
DevId	O	Unique device identifier
DevName	O	Name of the device
DevNo	O	Device number. Shall be unique in the consist network.
CstNetNo	O	Sequence number of the consist network where this device is connected to (see 4.3.3)
DevProperties	O	Static and dynamic device properties
DevFunctions	O	List of functions provided by the device

5.6.3 Inauguration control

5.6.3.1 Execution of the train inauguration

A train inauguration shall be automatically executed in the following cases:

- initial start-up of nodes
- train shortening (removing nodes from one end)
- train lengthening (appending nodes at one end)
- intermediate node insertion

5.6.3.2 Inauguration enforce

It should be possible for a user to enforce a new train inauguration.

NOTE Enforcing a new inauguration may be required if an entry in the own consist network directory or vehicle directory has been changed. Furthermore it may be needed for testing purposes.

5.6.3.3 Inauguration inhibit

It shall be possible to inhibit a train inauguration on user request, unless a train inauguration is unavoidable to save the train backbone from an integrity loss.

NOTE 1 Inauguration inhibit means to preserve sequence and orientation information obtained from the last train inauguration

NOTE 2 The possibility to inhibit train inauguration shall protect against temporally losing train backbone communication caused by new train inaugurations during critical operational phases like the coupling of two trains.

NOTE 3 An integrity loss of the WTB will happen for instance if an end node is gone. In that case a new train inauguration is unavoidable in order to re-terminate the bus physically.

5.6.3.4 User data communication

User data communication over the train backbone shall be stopped while the train inauguration is in progress. Train inauguration is finished after all active train backbone nodes have a valid and identical copy of the train network directory (see 5.6.2).

NOTE This prevents that user data are directed to the wrong destination.

5.6.3.5 Inauguration confirmation

The train inauguration process should provide a function which allows an application process to confirm the train backbone topology. The inauguration status (InaugStatus) of the train network directory shall then be set to “confirmed”.

Once confirmed, any changes to the train network directory with respect to the sequence and orientation of consists shall invalidate the train network directory by setting the inauguration status (InaugStatus) back to “unconfirmed”.

EXAMPLE UIC CODE 556 defines the number, orientation and sequence of vehicles as being subject of confirmation.

5.6.3.6 Inauguration correction

The train inauguration process should provide a function which allows an application process to correct a train backbone topology by inserting consists which have no active train backbone nodes. This results also in the generation of a corrected train network directory. The rules which define the correction procedure shall be defined in the application specific communication profile.

An inauguration correction shall always be followed by an inauguration confirmation; otherwise the correction shall be refused.

Corrections made by an application process should be preserved in case of new inaugurations.

If corrections cannot be preserved after a new inauguration, the inauguration status (InaugStatus) of the train network directory shall be set to “unconfirmed”.

EXAMPLE UIC CODE 556 allows the insertion of vehicles in the topology for the case that there are consists without active train backbone node. Upon new inaugurations the inserted consists are kept as long as this does not lead to conflicts.

5.6.4 Node states

5.6.4.1 Overview

The train inauguration protocol shall be implemented by a state machine (Figure 13), which performs the train inauguration and maintains the train network directory.

A minimum set of input signals shall be:

enforceInaug:	request a new train inauguration
inhibitInaug:	inhibit a train inauguration

Optional input signals are:

correctInaug:	correct the inauguration result
confirmInaug:	confirm the inauguration result

A minimum set of output signals shall be:

startUserDataEx:	start the transfer of user data between train backbone and consist network
stopUserDataEx:	stop the transfer of user data between train backbone and consist network
indicateTopoChange	indicate a change in topology if train inauguration is inhibit

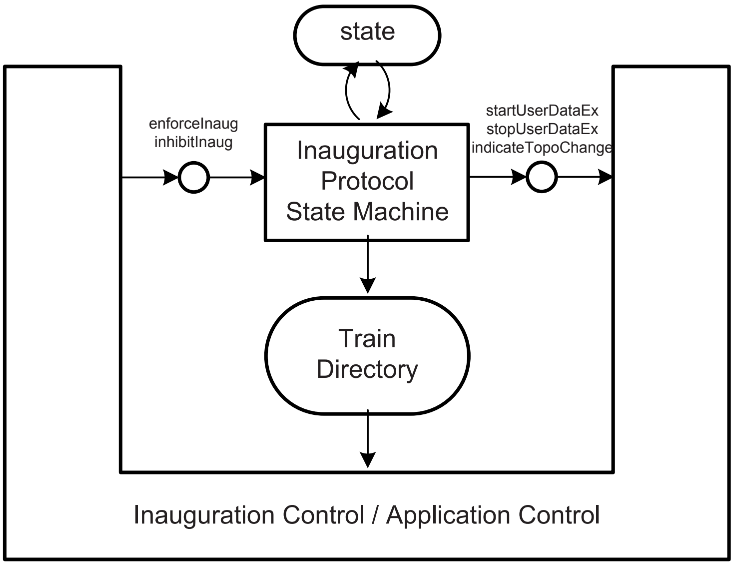

Figure 13 – Train inauguration block diagram

An active train backbone node shall be in one of the major node states[1] UNNAMED, NAMING and NAMED as depicted in Figure 14.

1 These are only the top level states. Depending on the Train Backbone technology used, there are a lot more sub-states.

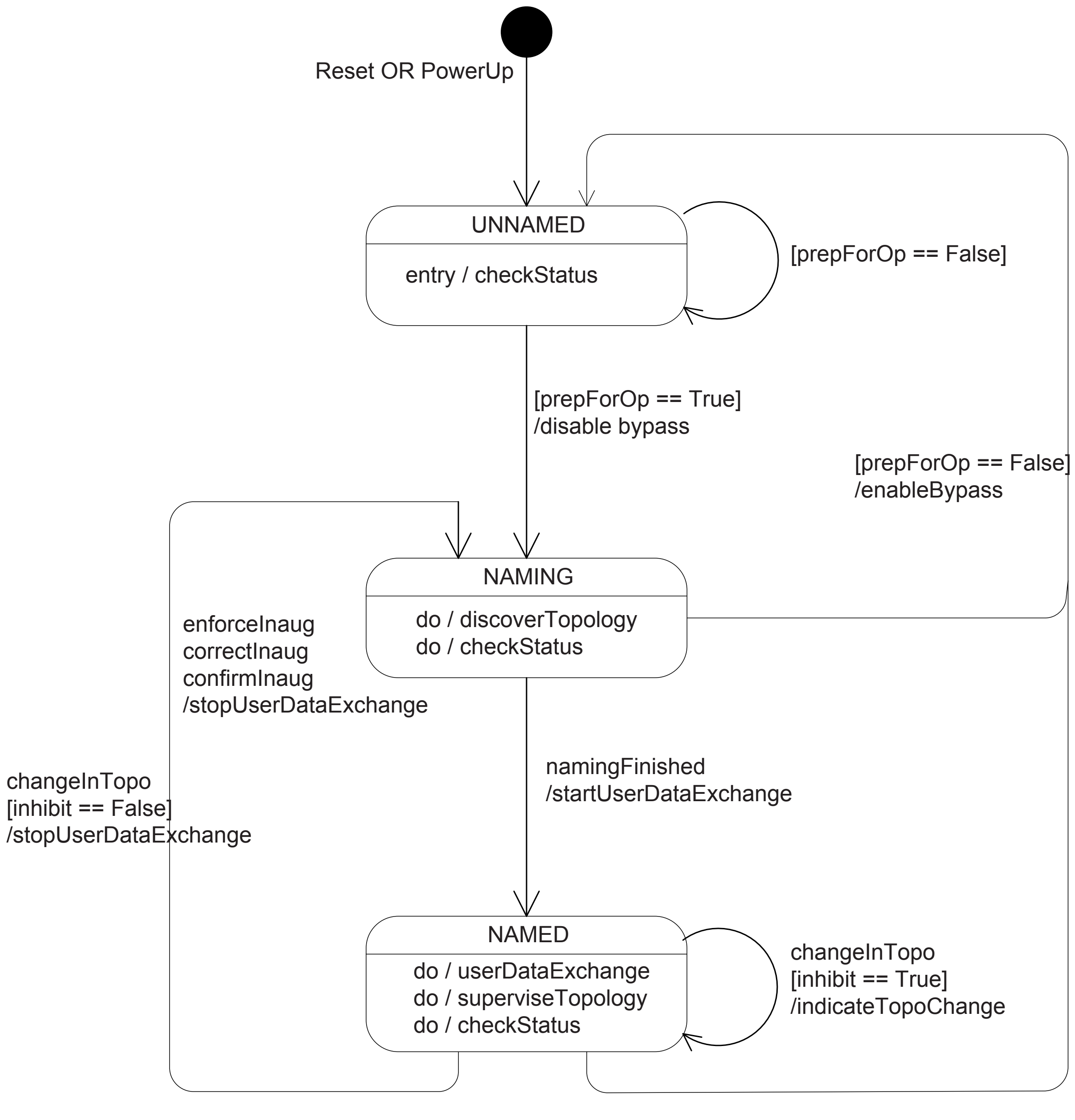

Figure 14 – Train inauguration state chart

5.6.4.2 State UNNAMED

This state is entered after power-up or reset. Node bypass is enabled. The node checks if it is able to launch train inauguration (“checkStatus”). If positive (“prepForOp == TRUE), the node will disable node bypass and change to state NAMING.

5.6.4.3 State NAMING

In this state the node is running the inauguration protocol as it is defined for the used train backbone. The inauguration is finished after the node has computed a valid train network directory. Thereafter the node changes to state NAMED and enables user data exchange over the train backbone. If the node detects an unrecoverable failure it shall return to state UNNAMED.

5.6.4.4 State NAMED

In this state user data are transferred over the train backbone. In parallel, the node checks for changes in the train backbone topology. If it is an end node, inauguration is “inhibit” and a train lengthening is detected, it remains in the state NAMED, but indicates a train lengthening. In all other cases of topology change, and also when inauguration is enforced, it disables user data exchange over the train backbone, starts the inauguration protocol and changes to state NAMING.

5.6.5 Node roles

After inauguration is an active train backbone node in one of the following node roles:

- intermediate node, if it has neighbor nodes in both directions
- end node, if it has a neighbor node in only one directions
- single node, if it has no neighbor nodes

End nodes and single nodes shall not pass user data towards the open end.

NOTE It must be avoided that nodes in end node or single node role send user data unintended to nodes which are coupled.

5.6.6 Performance

An important performance parameter for the train inauguration is the time T_{inaug} , specified by the maximal permitted time span between the occurrence of a change in the sequence or orientation of train backbone nodes and the completion of the train inauguration, supposing train inauguration is not inhibited. The completion of train inauguration is accomplished with the availability of an updated train network directory and a new TopoCount value in all train backbone nodes.

Suitable values for T_{inaug} shall be defined in the communication and application profiles of TCN.

EXAMPLE UIC CODE 556 defines a value of T_{inaug} = 1,4 s

6 Consist network

6.1 Contents of this clause

This clause specifies the basic features the consist network has to provide to ensure train wide communication in all types of trains. These features shall be common to all consist network technologies covered by this part of IEC 61375. As consist networks are used in different configurations, at first these configurations are listed. Subsequently the orientation on vehicle level is defined. The train wide communication between devices that are connected on consist network and which may use different communication techniques is enabled via gateway devices. The services to be provided by such gateway devices are described in this clause as well.

6.2 Scope of standardization

The standard parts related to the consist network technologies MVB, CANopen and ECN shall define at least for each of the consist network technologies (see Figure 15):

- The data communication interface (OSI Layers 1 until 7) of end devices connected to the consist network, as implemented by a communication protocol stack residing on the end device.
- The functions and services provided by the consist network to end devices.
- The gateway function for data transfer between train backbone and consist network. This gateway could be implemented as an application layer gateway (see 6.4.3) or as a router (see 6.4.4).
- The performances of the consist network.

The data communication interface between the consist network and the train backbone and the functions provided to the train backbone shall be subject of the standard parts relevant for the train backbone technologies WTB and ETB.

NOTE 1 The data communication interface between ED/CN comprises all the interface specifications and interface protocols from OSI Layer 1 (Physical Layer) until OSI layer 7 (application layer) if available. The standard does not prescribe how those specifications and protocols are implemented in the ED and the TBN, and hence does not require the specification of application programming interfaces for the communication protocol stacks (CPS) residing in the ED or the TBN. Nevertheless might it be helpful to provide a standardized application programming interfaces.

NOTE 2 It is not mandatory to specify the topology, the network components and the inner functions of the consist network.

NOTE 3 Performance parameters are for instance:

- latency of data transmission
- jitter of data transmission
- recovery time after a single network failure
- availability

NOTE 4 Functions and services are for instance:

- service for automatic address assignment to end devices
- service for network management

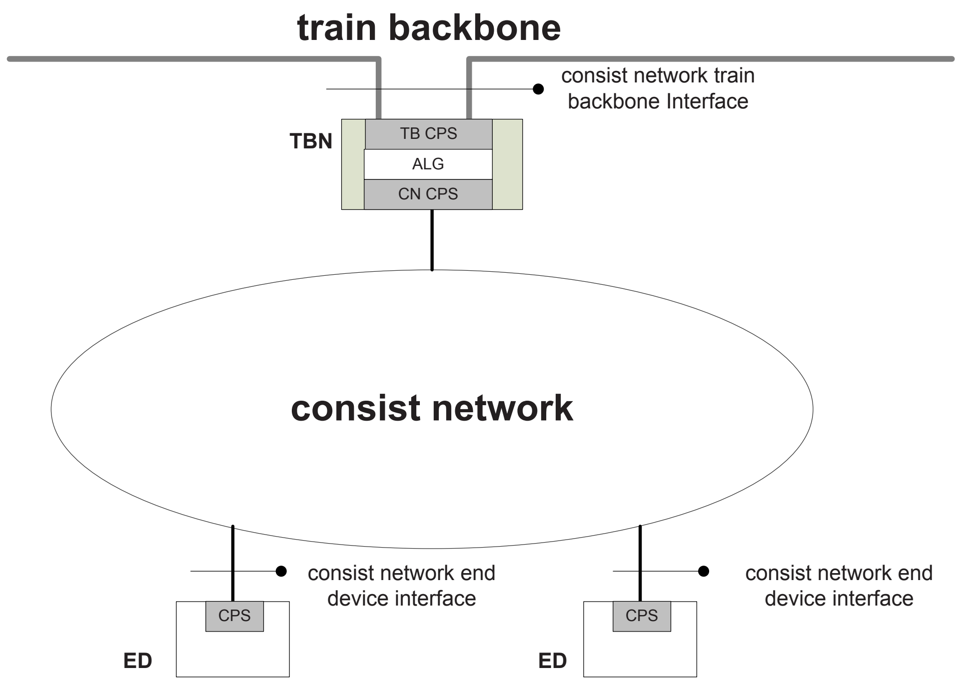

Figure 15 – Consist network standard interfaces

6.3 Consist network topology

6.3.1 Consist network based on bus technology (MVB, CANopen)

When a bus technology is used, communication devices are connected to a common data transmission medium which establishes a common broadcast and a common collision domain as shown in Figure 16.

In order to avoid collisions, a method has to be defined which controls bus access.

EXAMPLE The MVB controls bus access with a bus master.

To enhance availability, the common data transmission medium could be doubled.

The communication between consist network and train backbone shall be realized by a gateway. This gateway shall be implemented as part of the train backbone node.

The gateway should be redundant.

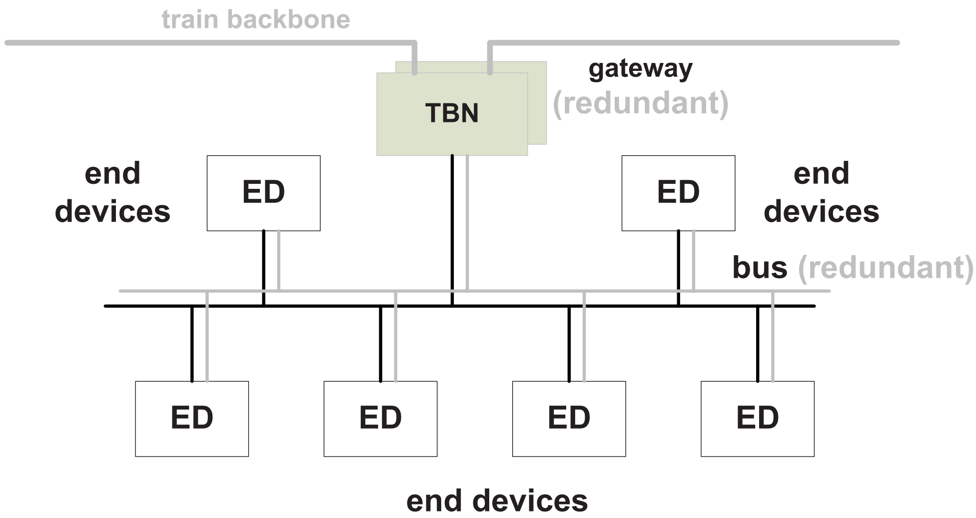

Figure 16 – Consist network (bus technology)

6.3.2 Consist network based on switched technology

In a switched technology end devices are interconnected by consist switch network devices as shown in Figure 17. Consist switches are devices with multiple ports (minimal two ports) and are responsible to forward data frames received on one port to either all (broadcast) or to selected ports. The switched network consists completely of point-to-point communication media, either between end devices and switches or between switches themselves.

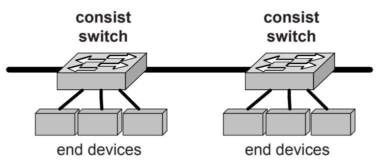

Figure 17 – Consist switches

In order to be used as part of the train communication network, the following general requirements are defined:

The communication media between any two communication devices should be full-duplex (separate media for receiving and sending). Half-duplex communication media (one media for receiving and sending) may be implemented as an option.

In order to manage collisions on half-duplex links, a method shall be defined which controls half-duplex media access.

To implement different levels of redundancy, the topology could be of any type (Figure 18):

a) linear;

b) ring;

c) ladder.

In physical switched network topologies which are different to a linear topology, a protocol shall establish a logical tree topology prior to any user data communication in order to prevent broadcast storms caused by loops.

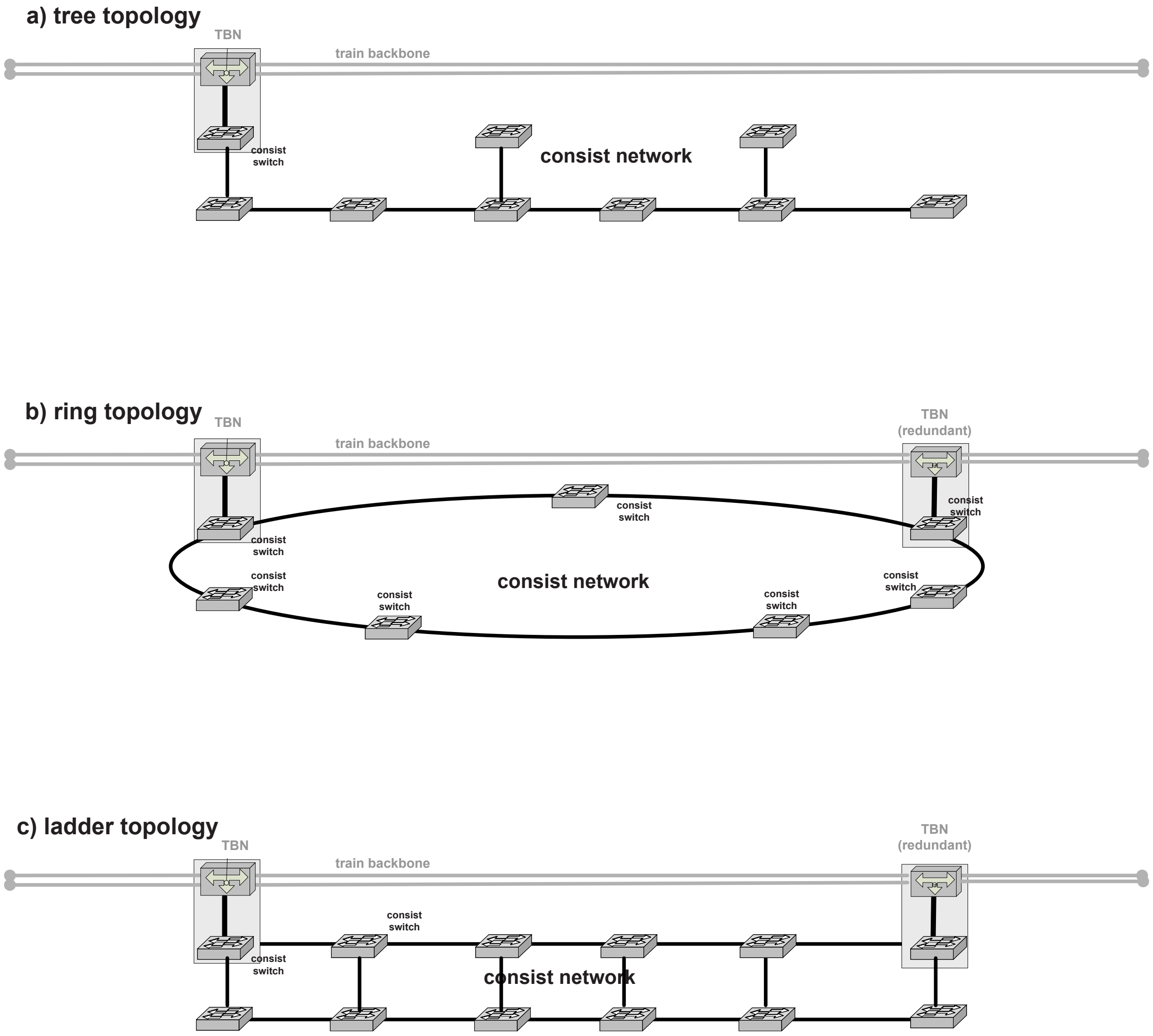

Figure 18 – Examples of consist network topologies (switched technology)

NOTE It is a design choice whether to combine a TBN and a Consist Switch in one device as sketched in Figure 18 or to keep it as separate devices.

For end device link redundancy, an end device may be connected to two different consist switches by two independent communication links (Figure 19).

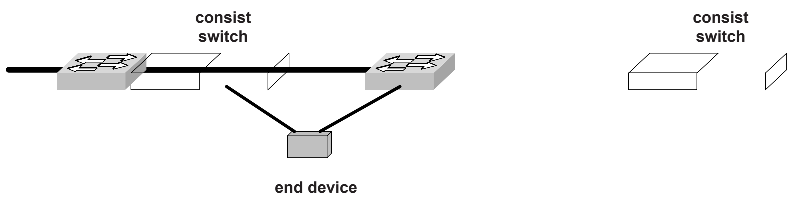

Figure 19 – End device connected to two consist switches

The connection between consist network and train backbone shall be realized by a gateway connected to a consist switch. This gateway should be implemented as part of the train backbone node.

6.3.3 Sub-networks

A consist network may be sub-structured into different sub-networks as for example depicted in Figure 20.

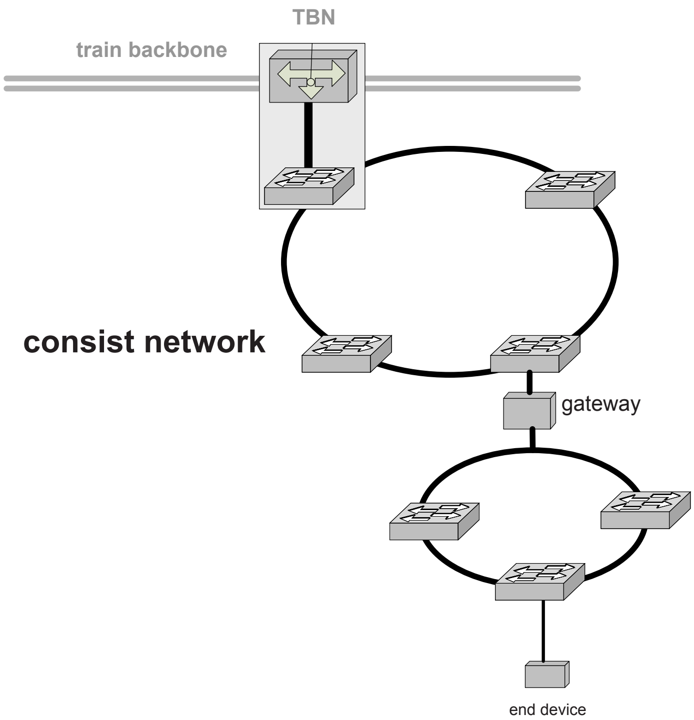

Figure 20 – Sub-networks in a consist network

6.3.4 Heterogeneous consist network

The consist network may also be composed of a combination of different technologies. For instance, a consist network may be implemented by means of several busses, connected to the train backbone via the gateway device. An example of such a consist network architecture is provided in Figure 21.

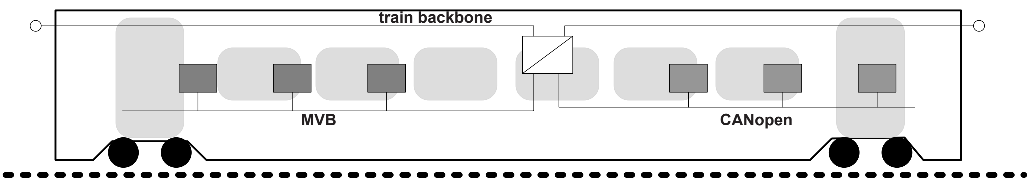

Figure 21 – Implementation example for two vehicle busses

6.4 Gateway

6.4.1 General

Gateways enable the communication flow in a train communication network between a train backbone and the consist network. This subclause provides a functional description of such gateway devices. In addition the service primitives for these gateways are defined.

6.4.2 Functional description

Train communication network architectures according to this part of IEC 61375 may use different communication technologies on the consist network level as well as on the train backbone level. An example of such heterogeneous train control network architecture is illustrated in Figure 22.

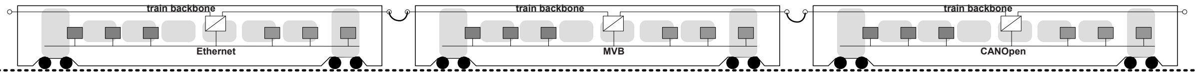

Figure 22 – Example of heterogeneous train control network architecture

Gateway devices are utilized to realize a proper train wide communication. These gateway devices provide a communication interface to the consist network as well as to the train backbone. Dependent on the used technologies for the train backbone and the consist network, those gateways may be implemented as either:

a) Application layer gateways operating on OSI layer 7.

b) Router devices operating on OSI layer 3.

NOTE It is highly recommended to use a homogeneous communication train backbone technology for train wide communication like WTB or ETB or both, in order to avoid gateways between train parts using different train backbone technologies, like one part with WTB and another part with ETB only.

6.4.3 Application layer gateway

6.4.3.1 General

Application layer gateways translate the services of one application layer into those of another application layer.

Bidirectional gateways enable the access from both sides of the gateway to the network on the related other side of the gateway. In particular, a bidirectional gateway between a consist network and a train backbone enables access from the train backbone level to the consist network and vice versa.

6.4.3.2 Service primitives for gateway devices

In order to interpret between the train backbone and the consist network, a gateway supports different service primitives. Service primitives are the means by which the gateway application and the network application layer interact. A bidirectional gateway between a consist network and a train backbone provides the following basic services at each communication interface:

- Request:
  a request is issued by the gateway application to the network application layer to request a service.
- Indication:
  an indication is issued by the network application layer to the gateway application to report an internal event detected by the network application layer or indicate that a service is requested.
- Response:
  a response is issued by the gateway application to the network application layer to respond to a previously received indication.
- Confirmation:
  a confirmation is issued by the network application layer to the gateway application to report the result of a previously issued request.

A service type defines the primitives that are exchanged between the network application layer and the gateway application for a particular service. A gateway between train backbone and consist network may support the following services:

– Local service: a local service involves only the local service element. The gateway application issues a request to its local service element that executes the requested service without communicating with peer service elements. A local service is illustrated in Figure 23.

Figure 23 – Local service

NOTE An example for a local service is the cyclic process data exchange between train backbone and consist network as implemented between MVB and WTB.

– Unconfirmed service: an unconfirmed service involves one or more peer service elements. The gateway application or the application of the network device issues a request to its local service element. This request is transferred to the peer service element that each passes it to its (their) application as an indication. An unconfirmed service is illustrated in Figure 24.

Figure 24 – Unconfirmed service

– Confirmed service: a confirmed service involves only one peer service element. The network device application or the gateway application issues a request to its local service element. This request is transferred to the peer service element that passes it to the network device application respectively to the gateway application as an indication. The network device application or the gateway applications issues a response that is transferred to the originating service object that passes it as a confirmation to the requesting service. This event is then indicated to the gateway application respectively to the network device application. The confirmed service is illustrated in Figure 25.

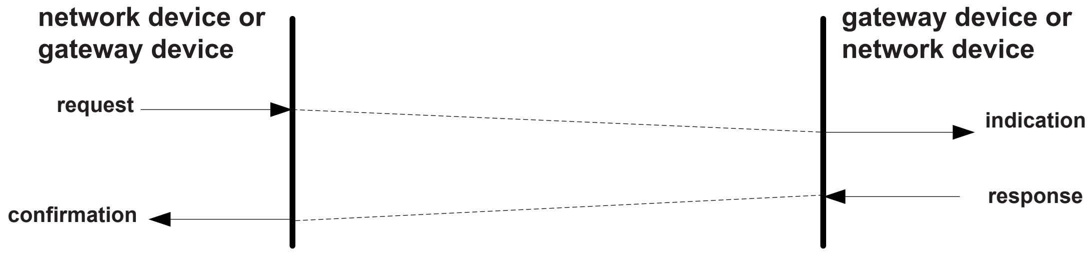

Figure 25 – Confirmed service

– Provider initiated service: a provider initiated service involves only the local service element. The service object (being the service provider) detects an event not solicited by a requested service. This event is then indicated to the gateway application. The provider initiated service is illustrated in Figure 26

Figure 26 – Provider initiated services

6.4.4 Gateway implemented by a router

Routers interconnect the train backbone and the consist network on OSI Layer 3. At least two routers are involved in the communication:

– Source router. This is the router in the train backbone node which belongs to the consist network of the source end device.

– Destination router. This is the router in the train backbone node which belongs to the consist network of the destination end device.

For routing user data packets from the consist network to the train backbone and vice versa, train network addresses as specified in 7.3.2.2 shall be used for destination addressing. If a valid train network destination address is used, the source router shall forward the user data packet to the destination router(s) and the destination router(s) shall forward the user data packet to the destination(s).

NOTE More than one destination router could be involved in case of point-to-multipoint communication (see 7.2).

EXAMPLE Message data exchange between WTB and MVB is performed by a router.

7 On-board data communication

7.1 General

This clause defines the general principles for the communication between applications in a train.

7.2 Communication patterns

7.2.1 Purpose

Communication patterns constitute the policy of data exchange between applications which exchange data over the TCN.

7.2.2 Definitions

Each data exchange between applications is provided by

- a data **sink**, which is an application instance consuming user data.
- a data **source**, which is an application instance producing user data.

The following data sending characteristics are considered:

- **Cyclic** sending**:** data is exchanged cyclically, e.g. every 0,1 s.

- **Sporadic** sending: data is exchanged when needed, e.g. an Event or Command.

Both data source and data sink can be initiator of a data exchange. Data exchange patterns initiated by a data source are called push patterns, data exchange patterns initiated by a data sink are called pull patterns.

The data exchange partners of an initiator can be at the time of sending:

- **Known** sources or sinks, in which case it can be single point or multi-point
- **Unknown** sources or sinks, in which case its **Range** is known and can be:
  - local sources or sinks,
  - remote sources or sinks, accessible through network, which can be:
    - in a vehicle
    - in a consist
    - in a closed train
    - in a train

EXAMPLE An unknown range of data sinks can for instance be all door controllers in a remote consist or all passenger displays in a specific vehicle. In that case the data source needs not know how many data sinks are available. Ranges of data sinks or data sources are typically implemented by defining groups.

7.2.3 Push pattern

7.2.3.1 General

In this pattern, the source provides the sink with the information when available.

7.2.3.2 Point to point

This pattern defines communication between one source and one sink as shown in Figure 27.

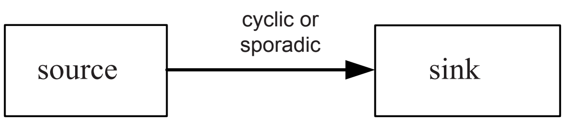

Figure 27 – Point to point communication pattern (push)

Push – Point to Point	
Data sending	Cyclic or sporadic.
Destination	1 case only: source knows sink.
Acknowledgement	3 cases: – cyclic without acknowledge, – sporadic with acknowledge – sporadic without acknowledge

EXAMPLE Command sent to a known door controller, with or without acknowledgement.

7.2.3.3 Point to multi-point

This pattern defines communication between one source and many sinks as shown in Figure 28.

Figure 28 – Point to multi-point communication pattern (push)

Push – Point to Multi-Point	
Data sending	Cyclic and sporadic.
Destination	2 cases: – source knows sinks. – source does not know the sink but the range, and interested sink subscribes.
Acknowledgement	3 cases: – cyclic without acknowledge, – sporadic with acknowledge – sporadic without acknowledge Only possible when destination known.

EXAMPLE Command sent to all door controllers which are responsible for the left doors.

NOTE A special case of this communication pattern is broadcasting to all sinks.

7.2.4 Pull pattern

7.2.4.1 General

In this pattern, the sink requests to the source the needed information.

7.2.4.2 Point to point

This pattern defines communication between one source and one sink as shown in Figure 29.

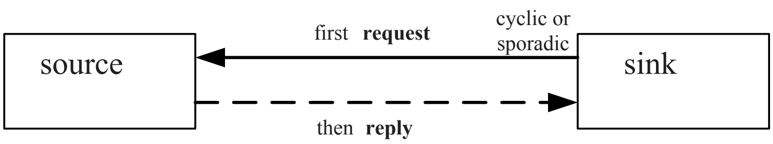

Figure 29 – Point to point communication pattern (pull)

Pull – Point to Point	
Data sending	Cyclic or sporadic.
Destination	1 case only: sink knows source.
Acknowledgement	3 cases: – cyclic without acknowledge

Pull – Point to Point	
	– sporadic with acknowledge – sporadic without acknowledge Reply can replace/include the acknowledge for the request. With or without acknowledge for reply.

EXAMPLE Vehicle controller asks known door controller to send status data.

7.2.4.3 Point to multi-point

This pattern defines communication between one sink and many sources as shown in Figure 30.

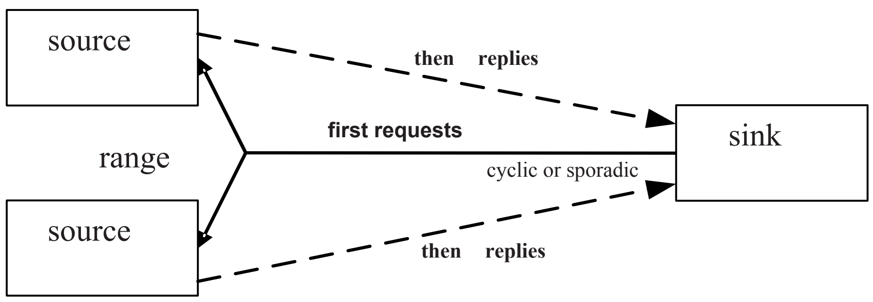

Figure 30 – Point to multi-point communication pattern (push)

Pull – Point to Multi-Point	
Data sending	cyclic or sporadic.
Destination	2 cases: – sink knows sources. – sink does not know the source but the range, and interested source subscribes.
Acknowledgement	3 cases: – cyclic without acknowledge – sporadic without acknowledge, – sporadic on first acknowledge (other acknowledges are ignored) – sporadic all acknowledge Acknowledge only possible when source known. Reply can replace/include the acknowledge. With or without acknowledge for reply.

EXAMPLE Vehicle controller asks all door controllers to send status data.

7.2.5 Subscription pattern

This pattern is used when a sink subscribes to a source as shown in Figure 31.

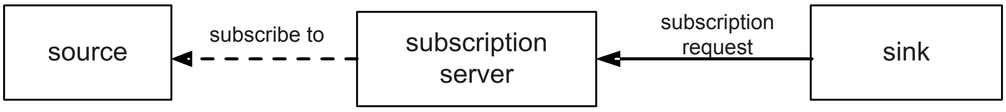

Figure 31 – Subscription communication pattern

The subscription server and source can be:

– combined as a unique entity,
– two different entities (e.g. subscription to a network message without knowing the source).

7.3 Addressing

7.3.1 General

This subclause defines the principles on addressing communication devices onboard trains, from train to ground and from ground to train. Addressing is defined on two levels: network layer addressing and application layer addressing ("functional addressing").

7.3.2 Network layer addressing

7.3.2.1 Consist network address

Each device connected to the consist network shall be identified by one or several consist network address(es). The consist network address shall be unique within a consist network.

NOTE Communication devices in different consists may have identical consist network addresses. This can be used to manufacture identical consists.

The consist network address could be coded in a way that the location of a communication device can be derived.

EXAMPLE The consist network address in MVB systems is the MVB device address. The consist network address in ECN systems is the IP device address.

7.3.2.2 Train network address

Train wide addressing of communication devices shall be possible with a train network address which is unique in the train. This train network address might change with each train inauguration; therefore this train network address is only valid in combination with the present train network directory version.

Communication devices which are connected to the train backbone (see 4.3.5) shall be identified by a train network address.

For communication devices which are connected to a consist network (see 4.3.4), the following applies:

– train network address and consist network address of a communication device may be identical;

– if train network address and consist network address of a communication device are not identical, a service shall be provided which maps the train network address to the consist network address(es).[2]

7.3.2.3 Group addresses

Communication devices may be grouped:

- On consist level. Here all members of the group belong to one consist network (= consist group). Consist group addresses assigned to those groups shall be unique within the consist. Memberships of consist groups are normally static.
- On train level. Here the members of a group belong to one or several consist networks (= train groups). Train group addresses assigned to those groups shall be unique within the train. Memberships of train groups may change with each train inauguration.

The definition of train groups shall be subject of the communication profiles as defined in 7.6.

NOTE Consist groups are typically pre-configured, but membership can be dynamic when communication devices (e.g. service computer) are temporarily connected.

7.3.2.4 Mobile address

Each MCG possesses at least two addresses, one static address towards the consist network or the train backbone and at least one static or dynamic address towards ground.

NOTE The methodology of assigning ground addresses to the MCG depends on the ground infrastructure and the used protocols.

7.3.2.5 Addressing single destinations

Each communication device located in the same consist network shall be addressable with its consist network address(es).

The train network address shall be used as a destination address of a communication device located in a remote consist network.

NOTE Communication devices sending to communication devices located in another consist network of the same consist or located in the same closed train could, instead of using the train network address directly, ask their local gateway to the train backbone, or another server, to generate the train network address based on information about the relative location of the destination communication device. This relative location information is not supposed to change with train inaugurations, because the composition of consists or closed trains is static. The advantage would be that the source communication device needs not take care of changes of the train network address, caused by train inaugurations, for sending to communication devices within the local consist or local closed train.

The train network address could be used as a destination address of a communication device located in the same consist network.

NOTE The last requirement expresses the possibility to address a consist network local communication device with the train network address, which might simplify application programs.

7.3.2.6 Addressing multiple destinations (option)

Each consist group located in the same consist network shall be addressable with its consist group address.

Each train group shall be addressable with its train group address.

NOTE The only way to address consist groups in other consist networks is to define a train group for this group.

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2 This is typically done in the router function of the gateway which connects the train backbone with the consist network.

7.3.3 Application layer addressing

7.3.3.1 Application addresses

A sending application process should be able to address a destination application process or a group of destination application processes in a way which abstracts from the used network technology. The details of application addressing should be defined in the application specific communication profile (see 7.6).

EXAMPLE 1 UIC Code 556 defines the tuples [source_consist;source_function] and [destination_consist;destination_function] for application addressing.

EXAMPLE 2 The EU project InteGRail defined an application addressing scheme based on Uniform Resource Identifier (URI) Strings in accordance to RFC 3986.

For the point-to-point communication between specific functions/functions instances (data packet containing the address of source and destination):

“ipt://instance.function@device.vehicle.consist.train.fleet”

For multicast communication (data packet based on publish/subscribe paradigm):

“ipt://instance.function@deviceGroup.vehicle.consist.train.fleet”

Considering the basic URI:

“user@host”

7.3.3.2 Functional addressing

Functional addressing is a special way of application addressing. Instead of addressing a specific communication device in a consist, an abstract function in this consist is addressed. For functional addressing the following shall apply:

Functions shall be identified by a unique function name.

It should be possible to address functions in a train’s consist by using the pair:

[function name, consist number].

The train backbone technology or consist network technology, respectively, has to provide a service which maps, transparently to the user, the function name to the related source and/or destination network address.

The definition of functions shall be subject of the communication and application profiles defined for TCN.

NOTE 1 A function name may also be represented by a number.

NOTE 2 The advantage of functional addressing is that a sending user application needs not know the destination network address of the communication device running the destination user application. Especially in open trains are destination network addresses in remote consists often not known.

EXAMPLE Addressing the function “door_control” in a remote consist.

7.4 Availability of data communication

Communication between ED connected to the same consist network shall not be interrupted by train inauguration.

Communication between ED connected to different consist networks, but belonging to one consist or one closed train, may be interrupted during train inauguration for the duration of the train inauguration.

7.5 Data classes

7.5.1 General

This sub-clause specifies the data classes which should be supported by the different consist network technologies and train backbone technologies defined in this part of IEC 61375.

7.5.2 Service parameters

Each specified data class is associated with communication service parameters which define the transmission characteristics of that data class. These service parameters include the quality of service (QoS) parameters.

A definition of service parameters is given in Table 6.

Table 6 – Service parameters

Service Parameter	Description
Data packet size	Volume of the data to be transmitted with one data packet. Measuring unit: number of octets
Data (packet) rate	Number of sent data packets per second. Multiplied with the data packet size * 8, it equals the (netto) data rate. Measuring unit: bits/s, Kbit/s, Mbit/s
Cycle time	Time interval between two data packet sending, for cyclically transmitted data. Measuring unit: seconds
Latency	Transmission time of the data packet from data source to data sink. Measuring unit: seconds
Jitter	Variance in transmission time for subsequent data packet transmissions. Measuring unit: seconds
Data integrity	Application data packet shall be received uncorrupted by the sink. Measuring unit: bit error rate (BER)
Safety Integrity	Probability that the following failures will be detected: a) data corruption b) sequencing error (unintended repetition, wrong sequence) c) timely delivery error d) authentication error (wrong source, wrong destination) Measuring unit: Probability P_{DU} of dangerous undetected failures per hour

EXAMPLE 1 A voice stream may be defined with the following service parameters:

data rate: 64 Kbit/s

latency: < 0,1 s

jitter: < 0,03 s

data integrity: $< 10^{-3}$ BER

EXAMPLE 2 Sending sporadically a control message to the brake controller, which is defined with the following service parameters:

data packet size:	64 bit
data rate:	~ 0,1 bit/s (mean value: 1 packet per 10 minutes)
latency:	< 0,2 s
data integrity :	$< 10^{-6}$ BER
safety integrity:	$P_{DU} < 10^{-7}$/h

7.5.3 TCN data class definition

For TCN five principal data classes are defined (Table 7). The table contains only a qualitative definition of the service parameters. A specific definition of the service parameters shall be given in the application specific communication profiles.

Table 7 – Principal data classes

Data class	Description/ Main characteristics
Supervisory Data	Data required for the train communication network operation, e.g. data for executing the train inauguration or data for network redundancy control Service parameters: as specified in the related parts of IEC 61375 NOTE these data are normally not visible to the application
Process Data	Real time data required for train control and monitoring. Service parameters: • low data rate • cyclic transmission • high data integrity • high safety integrity • low latency • low jitter
Message Data	Data required for train control and monitoring. Service parameters: • low to medium data rate • high data integrity • high safety integrity • medium latency
Stream Data – video – voice	Data packets of a video or voice stream. Service parameters: • high data rate • low to medium integrity • low latency • low jitter
Best Effort Data	Bulk data transfers and other activities that are allowed on the network but that should not impact the use of the network by one of the other data classes. Service parameters: not specified

EXAMPLE Typical examples for best effort data are:

- file transfer
- service access

7.6 Communication profile

A communication profile may be defined for specific application fields which rules how to use the communication technologies defined in this part of IEC 61375 for the specific purpose of this application.

The communication profile shall:

a) Select the network technologies for the train backbone and/or the consist network which the communication profile shall be based on (e.g. WTB or ETB).

b) Define the application domain (like open trains, closed trains etc.).

c) Define an application addressing scheme and the mapping to the addressing scheme provided by the selected communication technology.

NOTE An application addressing scheme might be especially valuable for train wide addressing. As defined in 5.2, the train backbone is set up by nodes, so from network point of view only nodes are addressable. But a real train user would like to address vehicles and consists instead of train backbone nodes, and might also want to address with respect to static or dynamic properties, like addressing the leading vehicle or addressing the dining coach. For doing so, a mapping between the user view and the network view needs to be defined, which shall also include the necessary algorithms for doing so.

d) Define how to populate the train network directory with application specific data, like vehicle and consist properties, identification information etc.

e) Define the rules for correcting the train backbone topology.

f) Define network services implemented on application layer which are needed but not supported by the selected communication technology.

g) Define the functional addressing.

h) Define data classes together with their service parameters which shall be supported by the selected communication technologies.

EXAMPLE A communication profile for international passenger trains based on WTB has been defined by UIC in the UIC Code 556.

Bibliography

IEC 61375-2-1, *Electronic railway equipment – Train Communication Network (TCN) – Wire Train Bus (to be published)*

IEC 61375-3-1, *Electronic railway equipment – Train Communication Network (TCN) – Multifunction Vehicle Bus (to be published)*

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