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TITLE:

Electronic railway equipment – Train communication network (TCN) – Part 1: General architecture

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NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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Electronic railway equipment - Train communication network (TCN) - Part 1: General architecture

FOREWORD

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IEC 61375-1 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2012. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Extension of train backbone topologies: aggregated and segregated topology;
b) Added independent consist orientation check with segregated train backbone topology;
c) Introduction of wireless technologies: wireless train backbone and wireless consist network;
d) Possibility of virtual networks;
e) Definition of data classes and protocol requirements suitable for the OMTS domain;
f) New clause about cybersecurity in train communication networks.

The text of this International Standard is based on the following documents:

Draft	Report on voting
9/XX/FDIS	9/XX/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts of IEC 61375 series, under the general title *Electronic railway equipment – Train communication network (TCN)*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,

– withdrawn, or

– revised.

INTRODUCTION

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

The creation of this fourth edition of the standard has been motivated by advances in technology, namely in the fields of Ethernet communication, wireless communication, and cybersecurity, which made it necessary to adapt or to extend some sections of the TCN general architecture. These changes will then further on be reflected in the detailed technical specifications given in subsequent parts of the IEC 61375 series.

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

a) for interconnecting vehicles in closed or open trains, this document specifies train backbones with different characteristics.
b) for connecting standard on-board equipment, this document specifies consist networks with different characteristics.

The general architecture of the TCN, which is defined in this document, does

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

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 might be additionally applicable to closed trains and multiple unit trains when so agreed between purchaser and supplier.

NOTE 1 For definitions 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

There are no normative references in this document.

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.

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

– IEC Electropedia: available at https://www.electropedia.org/

– ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
active train backbone node
train backbone node receiving a sequence number during train 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 process
element within a real open system which performs the information processing for a particular application

3.1.4
bridge
<in a train communication network> device which stores and forwards frames from one bus to another on the base of their link layer addresses

3.1.5
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 can receive the information and others not.

3.1.6
bus
<in a train communication network> 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

3.1.7
closed train
train composed of one or a set of consists, where the train composition does not change during normal operation

EXAMPLE Metro, sub-urban train, or high-speed train unit.

Note 1 to entry: Consists are coupled in a workshop to establish a closed train for operation.

3.1.8
communication device
device connected to the consist network or train backbone with the ability to transport, source or sink data

3.1.9
consist
single vehicle or a group of vehicles which are not separated during normal operation

Note 1 to entry: A consist can contain no, one or several consist networks.

3.1.10
consist network
communication network interconnecting communication devices in one consist

Note 1 to entry: Consist networks do not spread beyond consist boundaries.

3.1.11
consist network address
network address, which does not change after train inauguration and which is used to address communication device in the own consist network

3.1.12
consist sequence number
sequence number of the consist in the train as obtained during train inauguration

3.1.13
consist switch
network component used in consist network based on switched technology

3.1.14
cybersecurity
<in railway application> set of activities and measures taken with the objective identify, protect against, detect, respond to, and recover from unauthorized access or cyberattack which could lead to an accident, an unsafe situation, or railway application performance degradation

[SOURCE: CLC/TS 50701:2023, 3.1.32]

3.1.15
end device
unit connected to one consist network or to one set of consist networks prepared for redundancy reasons

3.1.16
end node
node which terminates the train backbone

3.1.17
essential function
function or capability that is required to maintain health, safety, the environment and availability for the equipment under control

Note 1 to entry: Essential functions include, but are not limited to, the safety instrumented function (SIF), the control function and the ability of the operator to view and manipulate the equipment under control. The loss of essential functions is commonly termed loss of protection, loss of control and loss of view respectively. In some industries additional functions such as history can be considered essential.

[SOURCE: IEC 62443-4-2:2019, 3.1.20]

3.1.18
function
<in a train communication network> application process which exchanges messages with another application process

3.1.19
gateway
<in a train communication network> connection between different busses at the application layer requiring application-dependent data analysis and protocol conversion

3.1.20
group address
address of a multicast group to which a device belongs

3.1.21
integrity
<in a train communication network> property of a system to recognize and to reject wrong data in case of malfunction of its parts

3.1.22
intermediate node
node which establishes continuity between two bus sections connected to it, but does not terminate them

3.1.23
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 (i.e. connected in the shape of a line)

3.1.24
local area network
<in a train communication network> part of a network characterized by a common medium access and address space

3.1.25
medium access control
<in a train communication network> sublayer of the link layer, which controls the access to the medium (arbitration, mastership transfer, polling)

3.1.26
medium
<in a train communication network> physical carrier of the signal: electrical wires, optical fibers, etc.

3.1.27
message
<in transmission systems> information which is transmitted in one or several packets from a sender to one or more receivers

3.1.28
multicast
transmission of the same message to a group of receivers, identified by their group address

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

3.1.29
multimedia data
data used for onboard multimedia and telematic services (OMTS), like video/audio streams or file transfer

3.1.30
multiple unit train
train comprising one or more train-units which can be controlled simultaneously from one cab and able to operate at normal speed in either direction without re-marshalling

3.1.31
network
<in a train communication network> set of possibly different communication systems which interchange information in a commonly agreed way

3.1.32
network address
address which identifies a communication device on network layer

3.1.33
network device
component used to set up consist networks and train networks

Note 1 to entry: These components can 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.

[SOURCE: IEC 60050-811:2017, 811-37-70, modified – Note 1 to entry has been modified.]

3.1.34
network layer
layer in the OSI model responsible for routing between different busses

3.1.35
network management
<in a train communication network> operations necessary to remotely configure, monitor, diagnose and maintain the network

3.1.36
node
<in a train communication network> device on the train backbone that acts as a gateway between train backbone and consist network

3.1.37
octet
byte
ordered set of eight binary digits, operated on as an entity

[SOURCE: IEC 60050-171:2019, 171-02-12]

3.1.38
open train
train composed of one or a set of consists, where the configuration can change during operation

EXAMPLE Locomotive-hauled international UIC (International Union of Railways, the international railways operators association) trains.

3.1.39
operator
enterprise or organization which is operating trains

3.1.40
operational data
data critical for train operation (TCMS), like propulsion control, brake control, doors control, lightning control or heating, ventilation, and air conditioning control

3.1.41
packet
<in a train communication network> unit of a message (information, acknowledgement, or control) transmitted by protocols on network or transport layer

3.1.42
realm
logical concept structuring train functions along coherent boundaries

3.1.43
receiver
<in a train communication network> electronic device which can receive signals from the physical medium

3.1.44
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."

3.1.45
ring topology
active network where each node is connected in series to two other nodes

Note 1 to entry: Ring can also be referred to as loop.

3.1.46
router
<in a train communication network> connection between two busses at the network layer, which forwards datagrams from one bus to another on the base of their network address

3.1.47
safety integrity
ability of a safety-related system to achieve its required safety functions under all the stated conditions within a stated operational environment and within a stated duration

[SOURCE: IEC 62425:2007, 3.1.50, modified – removal of "or product"]

3.1.48
service
<in a train communication network> capabilities and features of a sub-system (e.g. a communication layer) provided to a user

3.1.49
system under consideration
<in a train communication network> collection of assets that are needed to provide and operate a railway application including any relevant network infrastructure assets

Note 1 to entry: In a cybersecurity context as defined in IEC 62443-3-2:2020 [10], a system under consideration consists of one or more zones and related conduits. All assets within a system under consideration belong to either a zone or conduit.

3.1.50
switch
<in a train communication network> MAC bridge as defined in IEEE 802.1Q

Note 1 to entry: MAC means "Medium Access Control", a sub-layer within the Link Layer ruling which device is entitled to send on the bus.

3.1.51
topography
data structure describing the nodes attached to the train backbone, including their address, orientation, position and node descriptor

3.1.52
topology
possible cable interconnection and number of devices in a given network

3.1.53
train
combination of rolling stock coupled together

Note 1 to entry: Rolling stock includes banking locomotives.

3.1.54
train communication network
data communication network for connecting programmable electronic equipment on-board rail vehicles

3.1.55
train backbone
train bus
bus connecting the consists of a train, in particular the wire train bus, and which conforms to the TCN protocols

3.1.56
train backbone node
node
<in a train communication network> device on the train backbone that acts as a gateway between the train backbone and the consist network

3.1.57
train backbone node number
node address
node number
unique number assigned to a node during train inauguration indicating the position of the train backbone node on the train backbone

Note 1 to entry: This number can be used as part of the train network address for addressing devices in the consist, the train backbone node belongs to, from any location in the train.

3.1.58
train composition
sequence, orientation and characteristics of consists which represent a train

3.1.59
train directory
data structure which describes the train composition and provides user information about the consists

3.1.60
train inauguration
operation executed in case of train composition change, which gives all nodes of the train backbone their train backbone node number, their orientation and information about all named nodes on the same backbone, and which determines the actual train composition

3.1.61
train network address
dynamic network address, which is used to address communication devices in other consist networks

Note 1 to entry: The train network address can change after each inauguration.

3.1.62
train network directory
data structure which describes the sequence of train backbone nodes, the sequence of consist networks and the orientation of the consists in which the nodes are located

3.1.63
transport layer
layer of the OSI model responsible for end-to-end flow control and error recovery

3.1.64
wireless access point
active network device, using a wireless network interface to offer access to the consist network

3.1.65
wireless end device
active end device, using a wireless network interface to exchange data within the consist network

3.2 Abbreviations and acronyms

ALG	Application layer gateway
BER	Bit error rate
CAN	Controller Area Network
CCN	CANOpen Consist Network
CCS	Command, control and signalling
CCU	Consist control unit
CN	Consist network
CPS	Communication protocol stack
ECN	Ethernet Consist Network
ED	End device
ETB	Ethernet train backbone
ETBN	Ethernet train backbone node
GCG	Ground communication gateway
HFR	Hazardous failure rate
HVAC	Heat, ventilation and air conditioning
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocols
IT	Information technology
LAN	Local area network
MAC	Medium Access Control
MCG	Mobile communication gateway
MVB	Multifunction vehicle bus
ND	Network device
OMTN	OnBoard Multimedia and Telematic Network
OMTS	OnBoard Multimedia and Telematic Services
OSI	Open System Interconnection
OT	Operational technology
QoS	Quality of service
RFC	Request for comments
RFID	Radio frequency identification
SuC	System under consideration
SW	Software
TB	Train backbone
TBN	Train backbone node
TC	Train connectivity
TCMS	Train control and management system
TCN	Train communication network
TPN	Train passenger network
TPS	Train passenger services
UIC	International Union of Railways
UML	Unified modelling language
URI	Uniform resource identifier

VLAN	Virtual local area network
WAP	Wireless access point
WED	Wireless end device
WiFi	Wireless fidelity
WLCN	Wireless consist network
WLTB	Wireless train backbone
WLTBN	Wireless train backbone node
WTB	Wire train bus

3.3 Conventions

3.3.1 Base of numeric values

All numeric values use a decimal representation unless otherwise noted.

Binary and hexadecimal values are represented using the ASN.1 (ISO/IEC 8824-1:2021) convention [6][1].

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

3.3.2 Naming conventions

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 1 "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 2 "indicateTopoChange"

3.3.3 State diagram conventions

State diagrams are defined following the notation of UML state machines (ISO/IEC 19501:2005 [7]).

4 Basic architecture

4.1 General

Clause 4 specifies the hierarchical network architecture of the train communication network together with the main characteristics of its parts and the interfaces between them.

Annex A describes the overall on-board IT/OT architecture to provide some background of the environment the TCN is embedded in. It also describes some potential network configurations.

1 Numbers in square brackets refer to the Bibliography.

4.2 Technology and components

4.2.1 Technology classes

This document 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 three technology classes: either the bus technology class (WTB, MVB, CCN), the switched technology class (ETB, ECN) or the wireless technology class (WLCN, WLTB). 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, one end device is connected, via point-to-point transmission media, 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. The wireless technology class connects end devices 'over the air' via radio, forming a broadcast and collision domain. In TCN, different technology classes can be combined, as for instance to connect end devices wireless to a wired train backbone.

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 defines whether it is referred to as network device or end device.

4.3 Hierarchical structure

4.3.1 Network levels

This document 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.

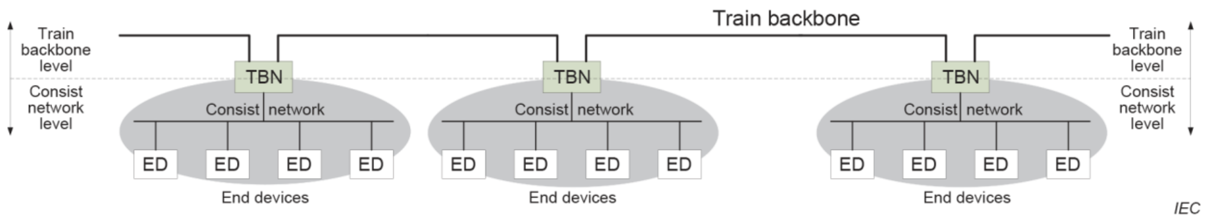


Figure 1 – Train backbone and consist network

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

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

a) 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 can 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.

b) 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.

c) 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.

d) From a cybersecurity perspective, it is mandatory to have a separation between the train-wide accessible train backbone and the only locally accessible consist network. Data transfer between the two levels shall be monitored and filtered to protect the consist network from cyberattacks originating from train backbone level and vice versa.

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 can have 0, 1 or more train backbone nodes.

To avoid a single point of failure on TBN supported essential functions, at least 2 train backbone nodes shall be provided per consist unless their omission can be justified.

NOTE A consist without a train backbone node is the special case of a "cable vehicle" as it is specified in UIC 556 [3]: consists that are not capable of train inauguration, which, however, are fitted with a cable for data transmission.

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 can contain no, one or several consist networks as depicted in Figure 2 as an example of a consist with two consist networks.

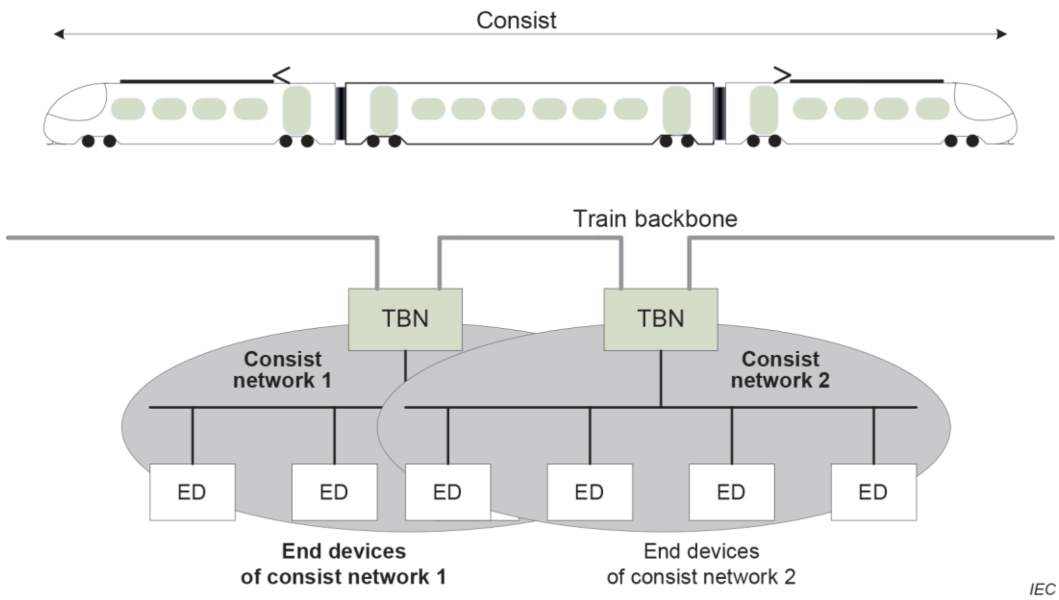


Figure 2 – Example of consist with 2 consist networks

A specific end device shall be connected to one consist network.

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

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

EXAMPLE 1 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 consecutive closed train network numbers with start value = 1.

EXAMPLE 2 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.

If the consist networks in a consist belong to different cybersecurity zones, cybersecurity measures shall be applied for zone protection.

EXAMPLE 3 Consist network 1 in Figure 2 is used for TCMS and consist network 2 is used for OMTS, and the data traffic exchanged between the networks is filtered by a firewall located in the TBN.

Only the train backbone shall be used for data exchange between consist networks.

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).

Consist networks belonging to the same consist can be connected to the same train backbone node.

A train backbone node can 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 can 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) can 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.

EXAMPLE 1 Consist network redundancy is used in ladder type consist network topologies.

EXAMPLE 2 Train backbone node redundancy with one active train backbone node is used in UIC trains equipped with WTB.

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.

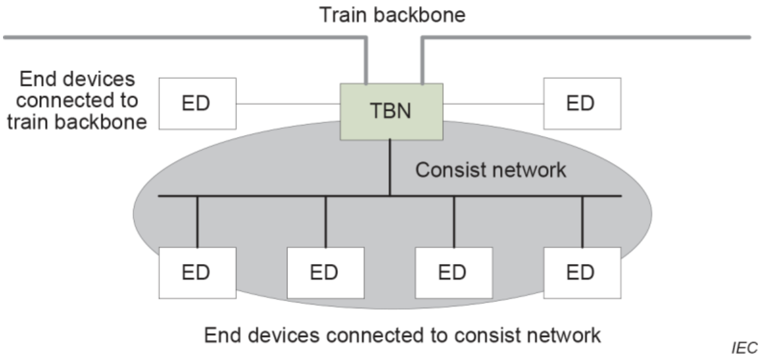


Figure 3 – End device connected to the train backbone (example)

4.4 Network configurations

Both train backbone and consist network can be implemented by one or a combination of the network technologies which are specified in this document.

The network technologies defined in this document can be used in following configurations:

For train backbone:

a) A train can use either WTB, ETB or WLTB.
b) A train can use WTB, ETB and WLTB in parallel.

EXAMPLE 1 WTB is used for operational data and ETB for multimedia data.

c) A train can use train backbones of different technology (e.g. WTB and ETB) which are connected by the mean of a gateway.
d) A train can use multiple ETB in parallel.

EXAMPLE 2 One ETB is used for operational data and another ETB for multimedia data.

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

For consist network:

a) Any of the consist network technologies MVB, CAN, WLCN or ECN can be used in a consist.
b) A combination of consist network technologies MVB, CAN, WLCN or ECN can 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.
c) Simple consists need not to have a consist network at all. End devices can 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). An MCG shall provide at least one interface to the ground network and one or more interfaces to an onboard network. In case the MCG is part of an end device, the MCG may not have an interface to the on-board network. Each consist should provide at least one MCG with a permanent or temporary, static or roaming connection to a ground communication gateway (GCG). There can however be simple consists without an 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 Often ground networks are 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.

Two use cases should 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 can be connected to the consist network, directly to a train backbone node or being part of an end device.

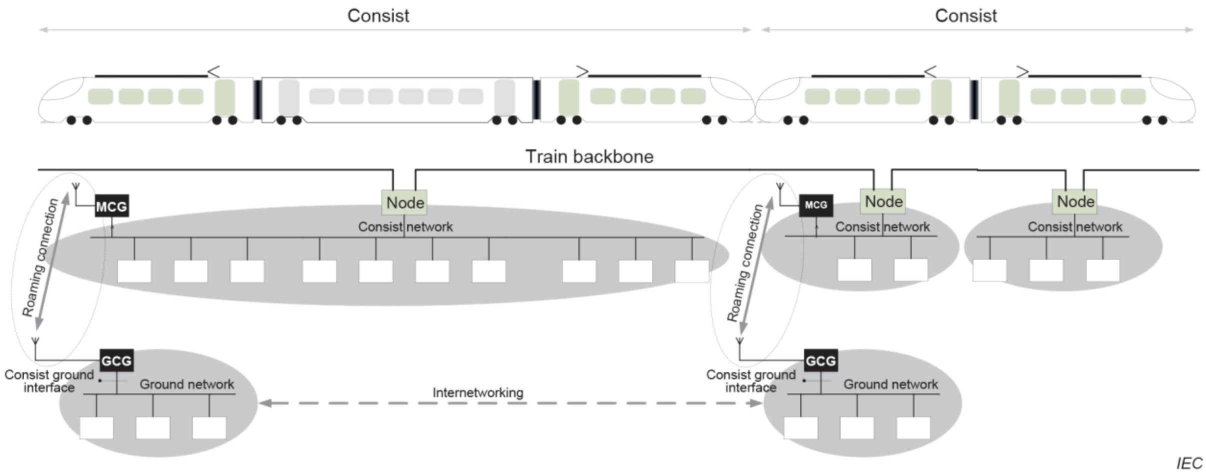


Figure 4 – Communication between train and ground (example)

EXAMPLE 1 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 are remotely accessible by at least the MCG connected to the first consist network of the same consist. Preferred is however a solution where end devices in any consist are accessible from either MCG. In this case accessibility changes in case of coupling/decoupling.

As an exposed component of the train communication network, the MCG can be a preferred target of cybersecurity attacks. To lower the attack risk to an acceptable level, suitable cybersecurity measures should be applied, see Clause 8 for more details.

EXAMPLE 2 As a cybersecurity measure, a firewall is installed between the consist network and the MCG.

5 Train backbone

5.1 General

Clause 5 specifies the basic features a train backbone shall 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 document. 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 defined, and finally the services of train backbone operation are defined.

5.2 Train backbone topology

5.2.1 General

This document 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.

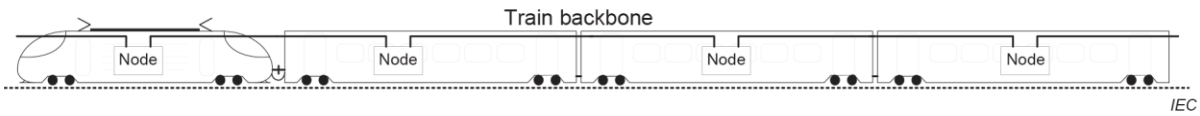


Figure 5 – Interfaces between consists

Train backbone nodes of different technology classes (WTB, ETB and WLTB) can be connected to the same train backbone by the mean of a gateway. However, interoperability of different technology classes is not considered by this document.

If the train backbone technology, like Ethernet [2], supports a virtualization (Virtual Local Area Network, VLAN), multiple train backbones of same technology class can also be virtual.

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, to send data selectively in one direction, and to determine the sender direction of received data.

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

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

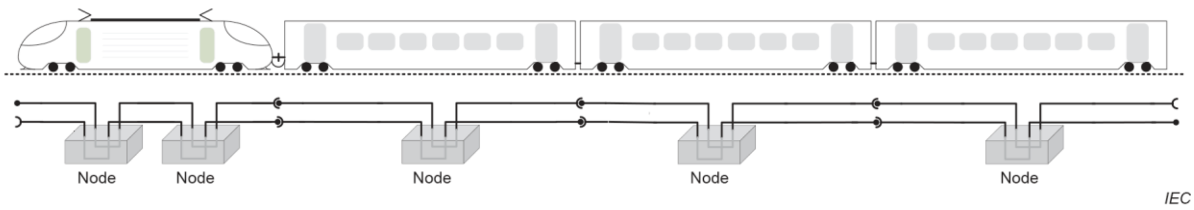


Figure 6 – Train backbone bus topology

5.2.3 Train backbone based on switched technology

5.2.3.1 General

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

To support redundancy, the data transmission medium shall be doubled. There are two potential configurations of transmission medium redundancy:

– Aggregated transmission media, see 5.2.3.2
– Segregated transmission media, see 5.2.3.3

Configurations with aggregated transmission media and Configurations with segregated transmission media cannot interoperate.

NOTE Both train backbone configurations have their specific pros and cons. Configurations with aggregated transmission media require a lower number of components but are more susceptible to single node failures. Configurations with segregated transmission media require more components but have a full separation of the transmission paths and are less susceptible to single node failures (e.g. node destroyed by local fire). This makes communication in general more reliable and supports seamless communication redundancy.

5.2.3.2 Train backbone configurations with aggregated transmission media

In train backbone configurations with aggregated transmission media as shown in Figure 7, each train backbone node connects to both transmission media. Aggregated and segregated transmission media cannot be connected to the same train backbone.

A mechanism shall be provided which prevents that a powerless or not operating node interrupts both aggregated transmission media unintendedly.

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

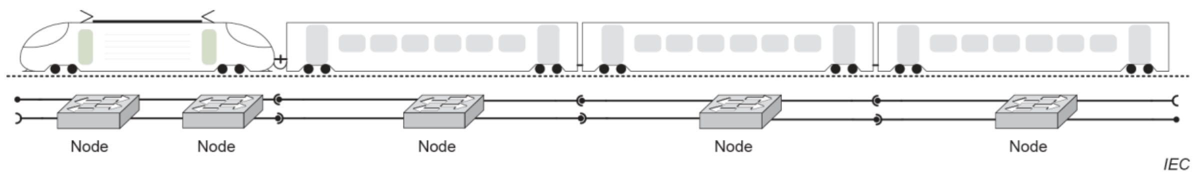


Figure 7 – Train backbone switched topology (aggregated transmission media)

5.2.3.3 Train backbone configurations with segregated transmission media

In train backbone configurations with segregated transmission media as shown in Figure 8, each train backbone node connects to only one of the two transmission media. This requires at least two train backbone nodes per consist. For common management of the train inauguration, the train backbone nodes in one consist need to be connected as for example via a common consist network.

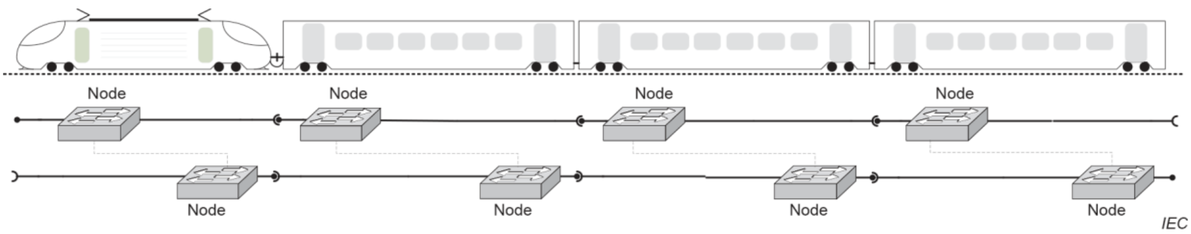


Figure 8 – Train backbone switched topology (segregated transmission media)

A mechanism shall be provided which prevents that a powerless consist interrupts both separated transmission media unintendedly.

NOTE A bypass relay used to bridge a node is not mandatory. Details are described in IEC 61375-2-5.

5.2.4 Train Backbone based on wireless technology

When a wireless technology is used, nodes shall provide a data transmission channel to all the other nodes, if present.

There are two kind of wireless train backbone topologies:

– wireless train backbone mesh topology, as shown in Figure 9;
– wireless train backbone base station topology, as shown in Figure 10.

NOTE 1 In the base station topology, the stationary ground facilities typically consist of a network with multiple base stations. For simplification, only one base station is shown in Figure 10 and Figure 12.

EXAMPLE Mesh topology is used in passenger trains as replacement of or extension to wired train backbone, base station topology is used for freight trains.

Mesh ETBNs and Base Station ETBNs cannot operate together as part of the same train composition.

NOTE 2 Profiles are to be defined to indicate usage of the technology in the respective operational environment.

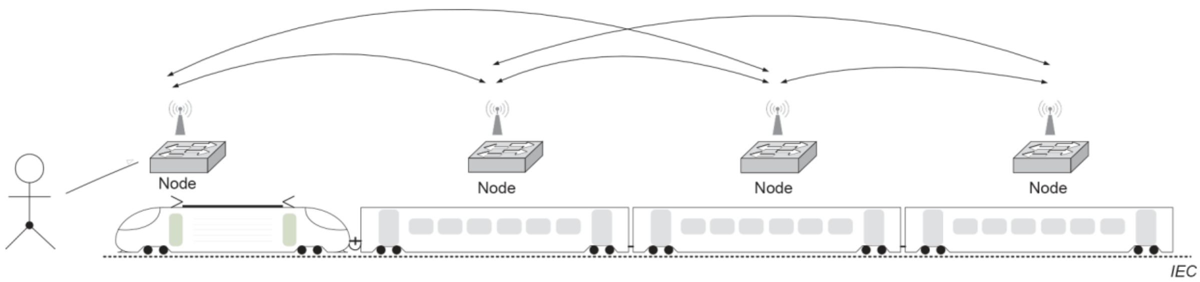


Figure 9 – Wireless train backbone mesh topology

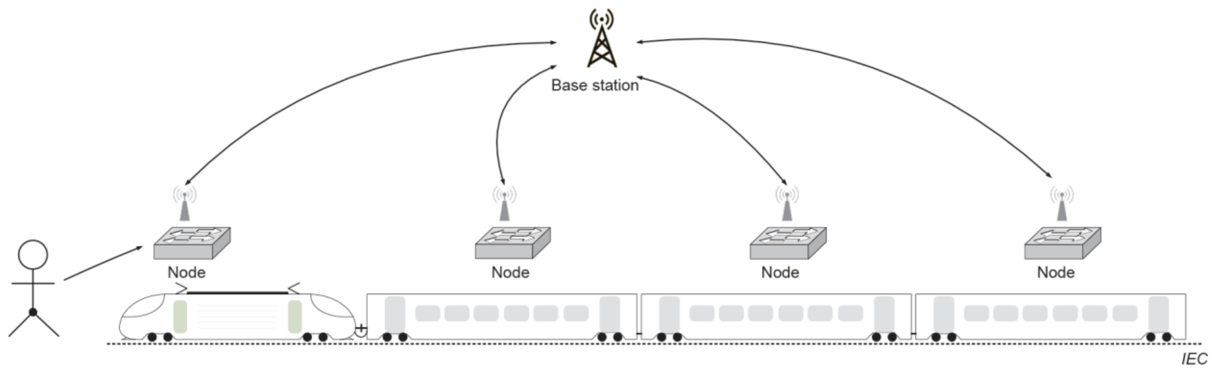


Figure 10 – Wireless train backbone base station topology

The driver, the operator, or both know beforehand which consists are to be coupled. Hence, the WLTBN shall know the network and the consist composition when mesh or base station topology are applied.

NOTE 3 The network association information contains the parameters necessary for wireless communication, such as frequency, channel, group ID and so on. The consist composition information contains the parameters necessary for train inauguration, such as the consist ID, orientation and direction and so on. All these information can be set by the driver or provided by ground system.

Because wireless technology has a certain range of communication, the WLTBN can communicate with nearby WLTBN that do not need to be coupled. A mechanism shall be provided to reduce interference between those WTLBN which should not be coupled. The WLTBN should identify and discard the frames from the uncoupled consist.

NOTE 4 In mesh topology, the interference can be reduced by means of directive antennas, different frequencies or channels used by WLTBN.

To support redundancy, the data transmission channel shall be doubled as shown in Figure 11 and Figure 12. The transmission equipment is divided into two groups. It requires at least two WLTBN per consist, and at the train level, each train backbone node only transmits data to the nodes in the same group. For common management of the train inauguration, the train backbone nodes in one consist need to get the same consist composition information from the driver or the operator.

NOTE 5 In order to discover adjacent consists in mesh topology automatically, it might be necessary to add additional point-to-point radio connections due to the absence of a physical link, as for example a RFID connection.

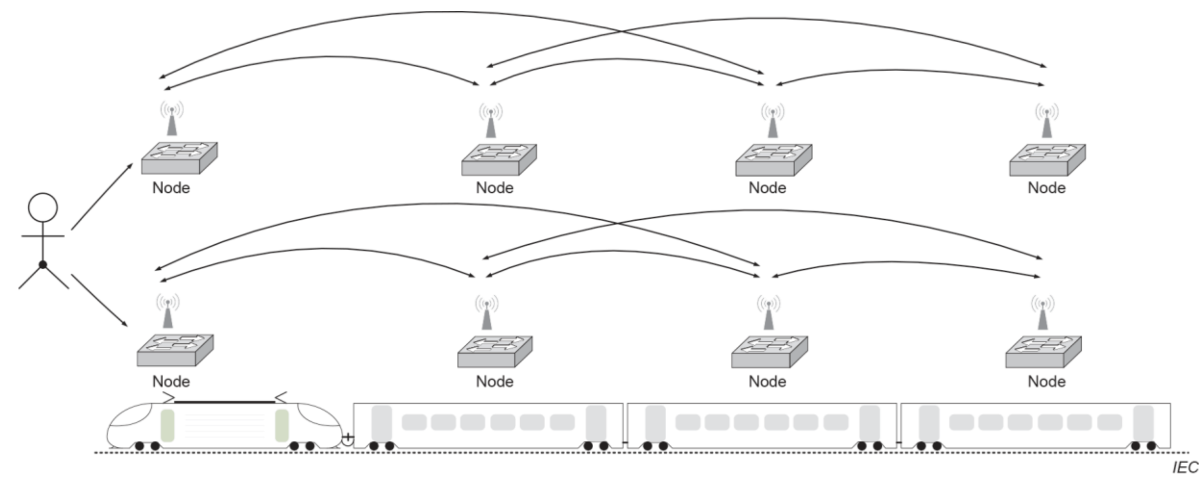


Figure 11 – Wireless train backbone mesh topology for redundancy

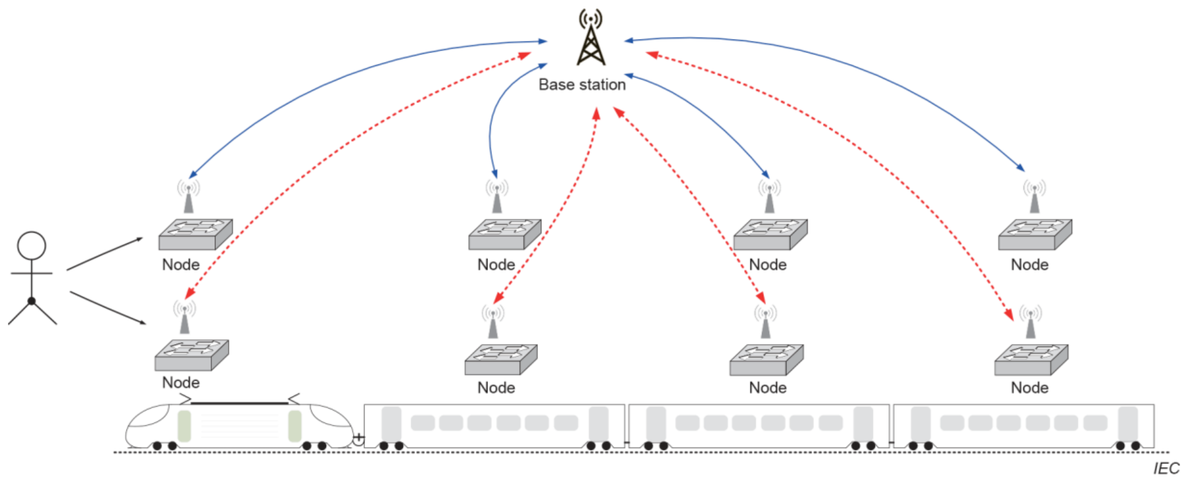


Figure 12 – Wireless train backbone base station topology for redundancy

NOTE 6 In the base station topology, the redundancy of the ground facilities depends on the level of redundancy required. For example, the wireless communication can use different frequencies provided by the same operator, or different frequencies provided by different operators.

NOTE 7 In case that signals of multiple base stations are overlapping, different WLTBN of the same train can communicate with different base stations.

Wireless technologies are susceptible to cybersecurity attacks. Therefore, suitable cybersecurity measures shall be applied to counter cybersecurity threats coming from outside or inside the train for the risks identified in a cybersecurity risk analysis (see 8.1).

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	A consist insertion takes place when train backbone nodes belonging to a consist in the middle of the train become activated later than their 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).

These sequence numbers can 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 in front of the WTB master node having numbers 63..33 and WTB nodes behind the WTB master node having numbers from 2 to 32.

5.5 Train directions

5.5.1 Vehicle

Directions of a vehicle are defined as follows:

a) one end of the vehicle is identified as Extremity 1, the other as Extremity 2;

b) 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 13.

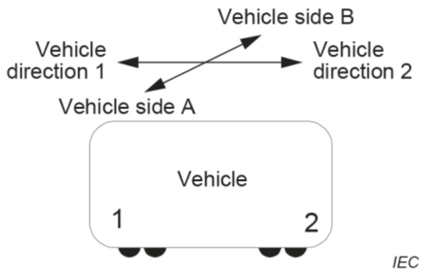


Figure 13 – Directions and orientation in a vehicle

5.5.2 Consist

Directions of a consist are defined as follows:

a) one end of the consist is identified as Extremity 1, the other as Extremity 2;

b) 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 which points west is named side A, the side which points east is named side B.

The directions of a vehicle inside a consist can 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 14.

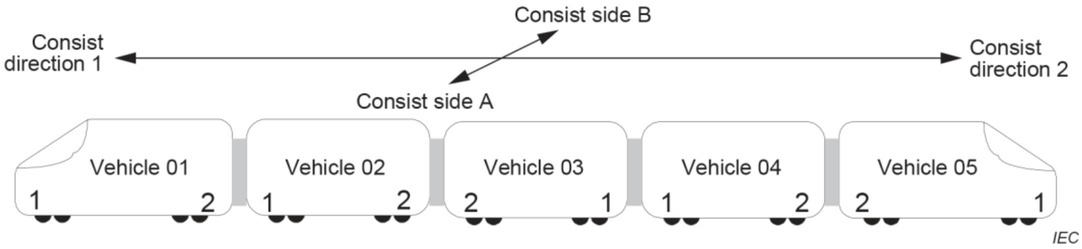


Figure 14 – Directions and orientations in a consist (example)

NOTE As shown in the example of Figure 14, vehicle 02 and vehicle 05 have an inverse orientation with respect to the consist direction.

5.5.3 Closed train

Directions 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) 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 can 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 of the closed train being consist number 1.

EXAMPLE Directions and orientations in a closed train with 2 consists can be as shown in Figure 15.

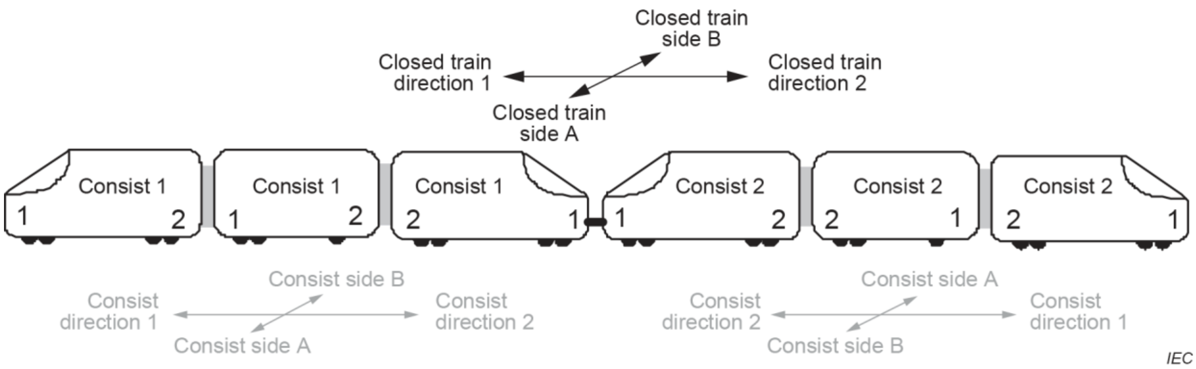


Figure 15 – Directions and orientations in a closed train

NOTE As shown in the example of Figure 15, consist 1has the same orientation as the direction of the closed train while consist 2 has an inverse orientation.

5.5.4 Train

5.5.4.1 General

Trains can be dynamically composed; therefore, the directions and orientations in a train can change. There are 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 of a train are defined as follows:

a) one end of the train is identified as Extremity 1, the other as Extremity 2;
b) 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 communication profile.

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 16.

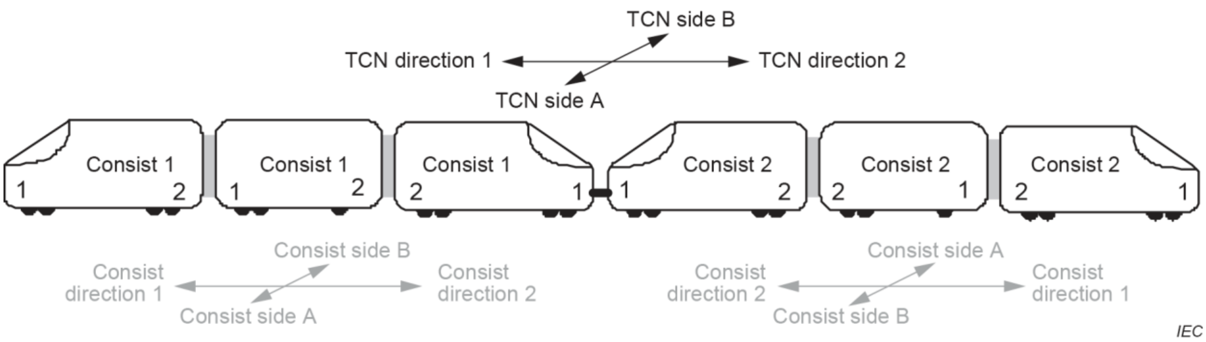


Figure 16 – Directions and orientations in train (TCN directions)

The direction of a consist in a train can be identical to the direction 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 16. Note that consist 2 direction is "inverse" with respect to the train orientation.

The direction of a closed train in a multiple unit train can be identical to the direction 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 consist at the Extremity 1of the train having assigned the consist number 1 (consist sequence number).

Closed trains in a multiple unit train are consecutively numbered with the closed train at the Extremity 1 having assigned the closed train number 1.

5.5.4.3 Application directions

Application directions will be defined in the communication profiles.

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

EXAMPLE For UIC, the train directions are specified in UIC 556 [3] and depend on the position of the leading consist.

5.6 Train inauguration

5.6.1 Objectives

The train inauguration procedure has two objectives:

a) train backbone inauguration: discover the present sequence of all active train backbone nodes connected to the train backbone, configure the train backbone nodes (e.g. assign a unique number and address to those nodes), and determine the present orientation of the consist, where a train backbone node is located in, with respect to the train orientation. All this information is stored in a train network directory. After train backbone inauguration, data communication between the different consists over the train backbone shall be possible;

b) train directory computation: share user information about the consist (including sequence and orientation information as obtained from the train network directory) with all other consists and compute with all this information the train directory.

5.6.2 Node sequence and orientation discovery

Each node shall provide a mechanism to discover its neighbour nodes in direction_1 and in direction_2. By exchanging this information with all other nodes connected to the train backbone, each node is capable to determine the sequence and orientation of connected train backbone nodes.

EXAMPLE To implement this mechanism in WTB, each WTB node disables its bypass during the discovery phase. In consequence, WTB detection telegrams can only be exchanged between the direct neighbours.

5.6.3 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, namely the sequence and orientation of connected train backbone nodes and information about consist networks connected to the nodes.

NOTE The train network directory related to WTB as specified in IEC 61375-2-1 is named WTB topography.

5.6.4 Train directory

At least one node in a consist shall compute, on the base of the train network directory, the train directory which also contains user defined data describing the properties and functions of the individual consists. The train directory should be made available to all devices (network devices and end devices) interested.

NOTE 1 The train directory related to WTB is specified in UIC CODE 556 [3] as part of the Node Address&Attribute Directory, NADI. The train directory related to ETB is specified in IEC 61375-2-3 as part of the Train Topology Database, TTDB.

NOTE 2 For OMTS, the train directory related to ETB is optional and specified in IEC 62580. The main difference between TCMS and OMTS is that on TCMS individual equipment is considered, whereas OMTS considers services.

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

The train directory should be structured:

– one common part for train parameters;

– a part for each consist with closed train, consist and consist network specific parameters ("consist directory");

NOTE 3 Consist directory for OMTS considers services and is defined in the IEC 62580 series.

– for TCMS: 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 1 An example of a train directory structure is given in Figure 17.

A train 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 directory shall be versioned:

– a static version number for the train directory data structure. This version number is referred to as "train directory version";
– at least one dynamic version number which shall change each time there is a change in the content of the train directory. This version number is referred to as "TopoCount" (topography counter).

NOTE 4 It can be more optimal to provide two dynamic versions, one which indicates train network directory changes (train composition changes) and one which indicates only parameter changes within the train directory without a change of the train network directory.

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 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 directory version (TopoCount) which was used for the preparation for the data.

NOTE 5 For the WTB, this version information is referred to as "topo_count".

EXAMPLE 2 Figure 17 depicts a train directory which is sub-structured into consist directory, vehicle directory and device directory. An explanation of the different parameters is presented in Table 2, Table 3, Table 4 and Table 5.

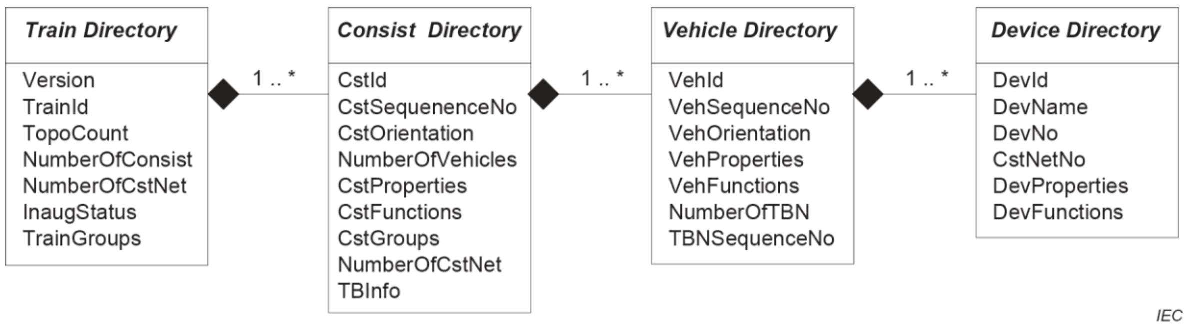


Figure 17 – Structure of train directory (example)

Table 2 – Train specific parameters (example)

Parameter	Description
Version	Version of the train directory data structure
TrainId	Unique identifier of the train
TopoCount	Dynamic version of the train directory content. Value changes with each new train inauguration
NumberOfConsist	Number of consists in the train
NumberOfCstNet	Number of consist networks in the train
InaugStatus	Train inauguration status: INVALID UNCONFIRMED CONFIRMED
TrainGroups	List of train groups, see 7.3.2.3

Table 3 – Consist specific parameters (example)

Parameter	Description
CstId	Unique consist identifier
CstSequenceNo	Consist sequence number in the train as defined in 5.5.4.
CstOrientation	Consist orientation with respect to the train orientation as defined in 5.5.4.
NumberOfVehicles	Number of vehicles in the consist
CstProperties	Consist properties, e.g. owner, operator, list of equipment, leading consist
CstFunctions	List of functions provided by the consist
CstGroups	List of consist groups, see 7.3.2.3
NumberOfCstNet	Overall number of consist networks in this consist
TBInfo	List and type of train backbones in the consist, number of consist networks connected to a specific train backbone

Table 4 – Vehicle specific parameters (example)

Parameter	Description
VehId	Unique vehicle identifier
VehSequenceNo	Vehicle sequence number in the consist (according to Figure 14)
VehOrientation	Vehicle orientation with respect to the consist orientation (acc. to Figure 14)
VehProperties	Static and dynamic vehicle properties
VehFunctions	List of functions provided by the vehicle
NumberOfTBN	Total number of train backbone nodes in this vehicle
TBNSequenceNo	Number of the train backbone node in this vehicle

Table 5 – Device specific parameters (example)

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

5.6.5 Train inauguration control

5.6.5.1 Execution of the train inauguration

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

– initial start-up of nodes;
– train shortening (removing consists from one end);
– train lengthening (appending consists at one end);
– intermediate consist insertion (inserting nodes in between);
– change of leading consist;
– inauguration correction.

5.6.5.2 Inauguration enforce

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

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

5.6.5.3 Inauguration inhibit

Inauguration inhibit means to preserve consist sequence and orientation information obtained from the last train inauguration.

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

NOTE 1 The possibility to inhibit train inauguration protects against temporally losing train backbone communication caused by new train inaugurations during critical operational phases like the coupling of two trains.

NOTE 2 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.

5.6.5.4 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 directory (see 5.6.3).

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

5.6.5.5 Inauguration confirmation

The train inauguration process should provide a function which allows an application process to confirm the train composition. The inauguration status (InaugStatus) of the train directory shall then be set to "confirmed".

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

EXAMPLE UIC CODE 556 [3] defines the number, orientation, and sequence of vehicles as being subject of confirmation.

5.6.5.6 Inauguration correction

The train inauguration process should provide a function which allows an application process to correct a train composition by inserting consists which have no active train backbone nodes or removing consists that were inserted earlier in that manner. This results also in the generation of a corrected train 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 train inaugurations.

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

EXAMPLE UIC CODE 556 [3] allows the insertion of vehicles in the topology for the case that there are consists without active train backbone node. Upon new train inaugurations the inserted consists are kept as long as this does not lead to conflicts.

5.6.6 Node states

5.6.6.1 Overview

The train inauguration protocol shall be implemented by a state machine (Figure 18), which performs the train inauguration and maintains the train directory.

A minimum set of inputs shall be:

enforceInaug:	request a new train inauguration
inhibitInaug:	inhibit a train inauguration
requestLeading	set or reset leading request

Optional inputs are:

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

A minimum set of outputs 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 inhibited
indicateLeadingState	Indicate the leading state of this consist

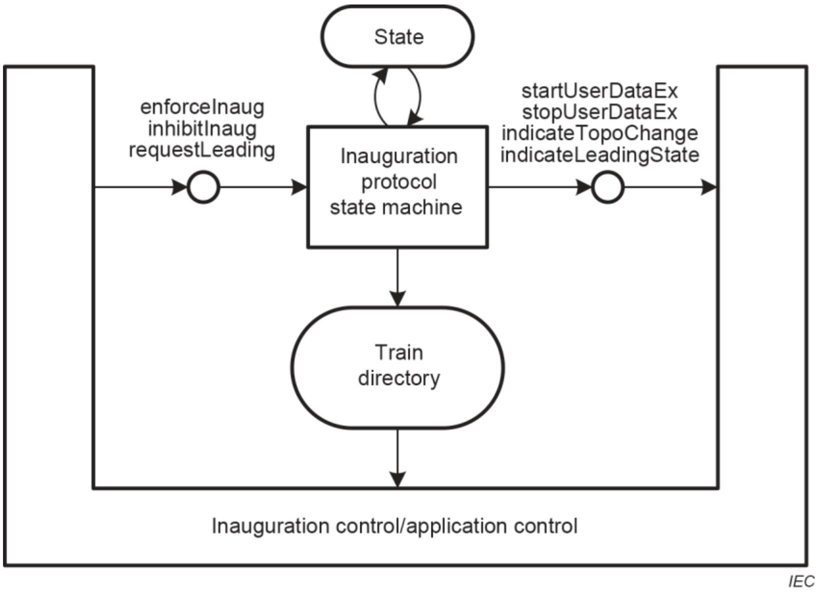


Figure 18 – Train inauguration block diagram

An active train backbone node shall be in one of the major node states[2] UNNAMED, NAMING and NAMED as depicted in Figure 19.

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

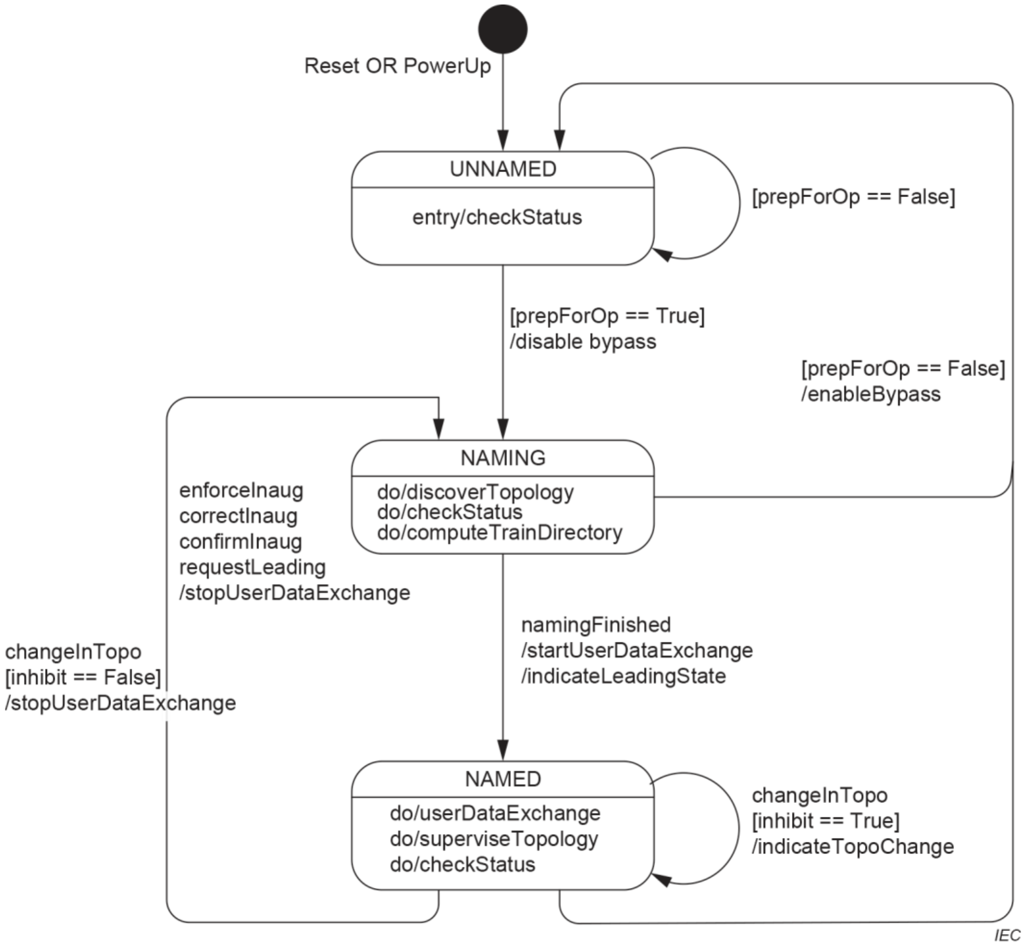


Figure 19 – Train inauguration state chart

5.6.6.2 State UNNAMED

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

5.6.6.3 State NAMING

In this state the node is running the train inauguration protocol as it is defined for the used train backbone. The train inauguration is finished after the node has computed a valid train 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.

5.6.6.4 State NAMED

In this state user data are transferred over the train backbone. In parallel, the node checks for changes in the train composition. If it is an end node, train 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 train inauguration is enforced, leading or correction are requested it disables user data exchange over the train backbone, starts the train inauguration protocol and changes to state NAMING.

5.6.7 Node roles

After train 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 direction;
– single node, if it has no neighbor nodes.

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

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

5.6.8 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 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 [3] defines a value of T_{inaug} = 1,4 s

5.6.9 Independent consist orientation check (Option)

A train backbone based on switched technology with segregated transmission media as defined in 5.2.3.3 can be used to determine consist orientation in an independent way (independent from the mechanism defined in 5.6.2).

For this, each CCU shall send a specific telegram, called "BEACON" telegram, to all other CCUs exclusively over one of the TB lines and shall include the identification of the used TB line inside the telegram. Receiving CCUs compare this identification with the identification of the transmission media from which the telegram has been received. If the identifications are different, the consists have opposite orientation. For redundancy, BEACON telegrams can be sent over both TB lines (see Figure 20).

EXAMPLE The CCU in consist 1 sends a BEACON over its TB line A. If the CCU in consist 2 receives this telegram on its TB line B, it will know that consist 2 has opposite orientation to consist 1.

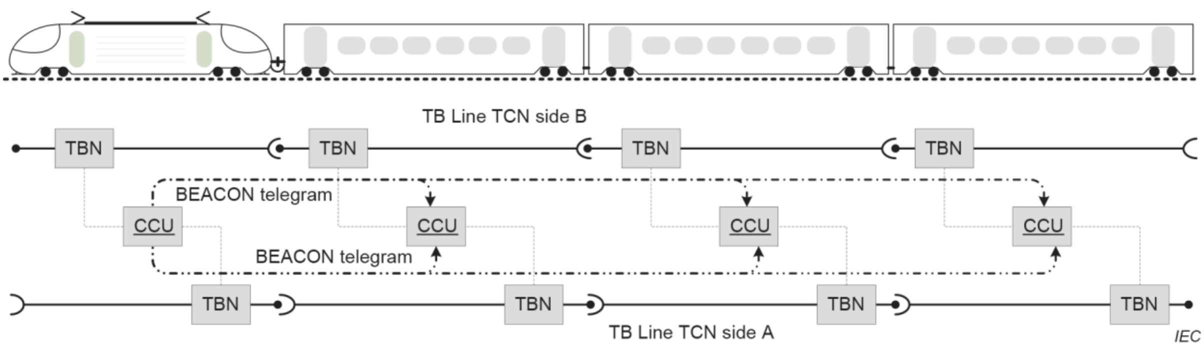


Figure 20 – Independent orientation check with BEACON telegrams

To ensure interoperability, the exchange of BEACON telegrams over the train backbone will be specified in other parts of the IEC 61375 series.

NOTE The exchange of BEACON telegrams over ETB will be ruled in IEC 61375-2-5 and IEC 61375-2-3.

6 Consist network

6.1 General

Clause 6 specifies the basic features the consist network shall provide to ensure train wide communication in all types of trains. These features shall be common to all consist network technologies covered by this document. 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 can use different communication techniques is enabled via gateway devices. The services to be provided by such gateway devices are defined in clause 6 as well.

6.2 Scope of standardization

The standards related to the consist network technologies MVB (IEC 61375-3-1), CCN (IEC 61375-3-3), WLCN (not available at the time of release of this document) and ECN (IEC 61375-3-4) shall define at least for each of the consist network technologies (see Figure 21):

– the data communication interface (OSI Layers 1 until 7 [5]) 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 can 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 standards relevant for the train backbone technologies WTB (IEC 61375-2-1), WLTB (IEC 61375-2-7) and ETB (IEC 61375-2-5).

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, it can be helpful to provide a standardized application programming interface.

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

NOTE 1 Performance parameters are for instance:

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

NOTE 2 Functions and services are for instance:

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

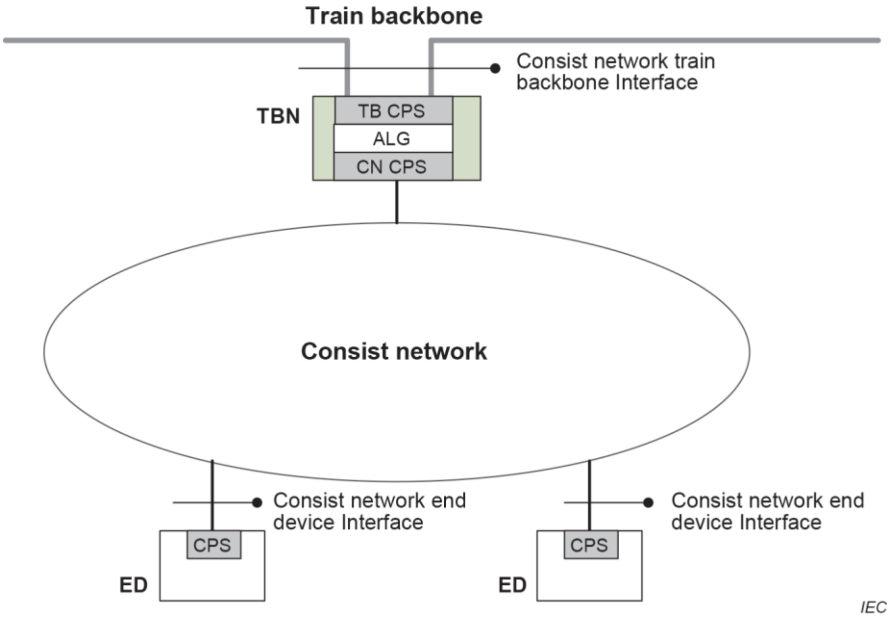


Figure 21 – Consist network standard interfaces

6.3 Consist network topology

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

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 22.

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 should 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.

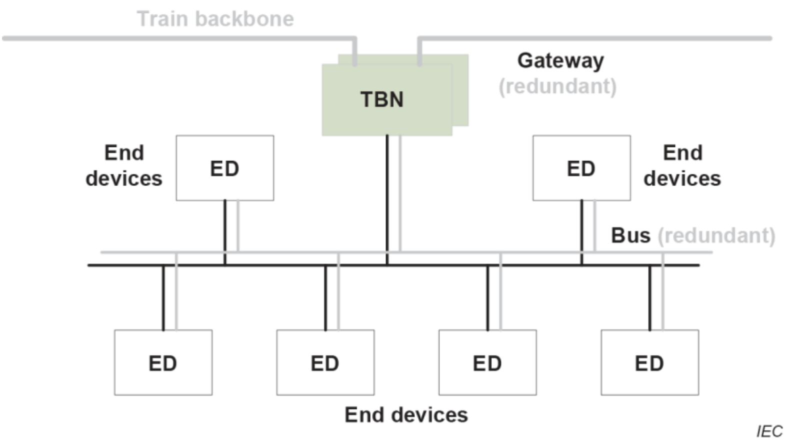


Figure 22 – Consist network (bus technology)

6.3.2 Consist network based on switched technology (ECN)

In a switched technology end devices are interconnected by consist switch network devices as shown in Figure 23. Consist switches are devices with multiple ports (minimal three 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.

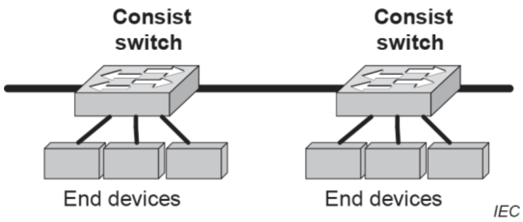


Figure 23 – Consist switches

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

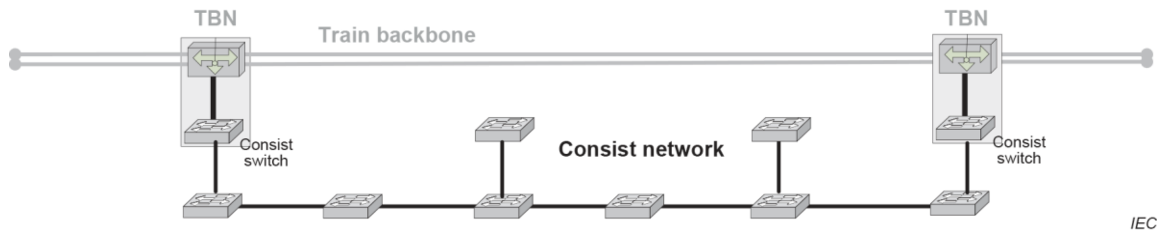
The communication media between any two communication devices should be full duplex (separate media for receiving and sending). Half-duplex communication media (one media for receiving and sending) can be implemented as an option.

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

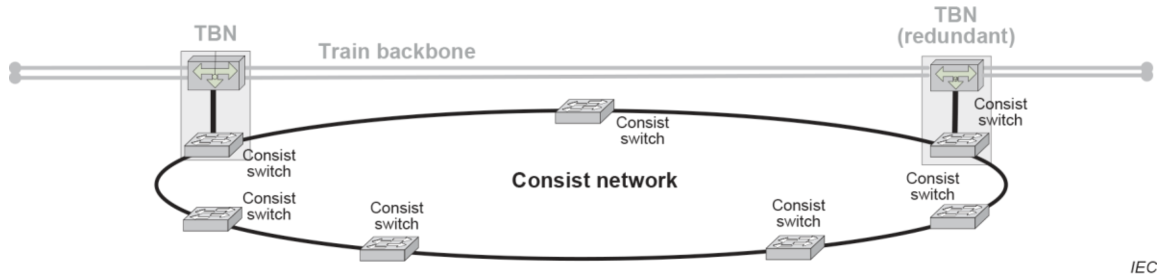
To implement different levels of redundancy, the topology can be of any type (Figure 24):

a) linear topology – not tolerant to single network failures: single network failure may break consist wide communication;
b) ring topology – tolerant to single network failures: single network failure does not break consist wide communication;
c) ladder topology – tolerant to single and to most double network failures: single network failure and most double network failures do not break consist wide communication.

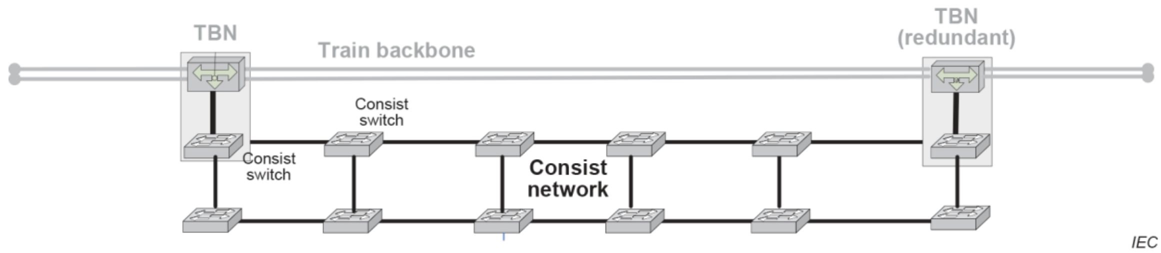
In physical switched network topologies, a protocol shall establish a logical tree topology prior to any user data communication in order to prevent broadcast storms caused by loops.



a) linear topology



b) ring topology



c) ladder topology

Figure 24 – 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 24 or to keep it as separate devices.

For end device link redundancy, an end device can be connected to two different consist switches by two independent communication links (Figure 25). To use those links there are in principle two possibilities: either to use both Ethernet links in parallel ("dual homing") or to use one and have the other in standby ("bonding"). Dual homing with two active links can use a load balanced mode (data traffic balanced over both links) or a parallel mode, where frames are replicated at source, sent in parallel over both links, and the replica is eliminated at sink.

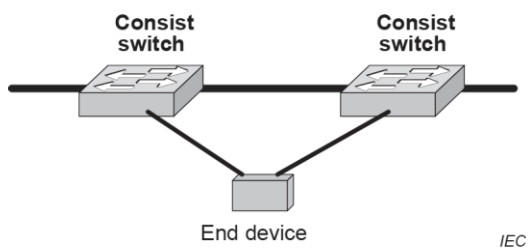
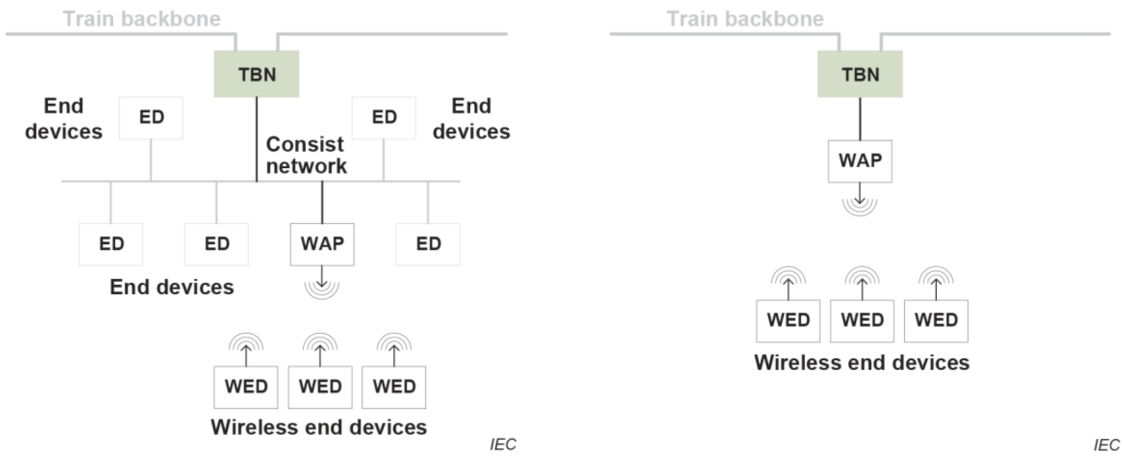


Figure 25 – End device connected to two consist switches

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

6.3.3 Consist network based on wireless technology (WLCN)

Consist networks can be, in part or in whole, implemented with wireless interconnections between end devices. The wireless consist network (WLCN) defined within the IEC 61375 series extends a (wired) ECN with the possibility to connect wireless end devices (WED). It is also possible to have a pure wireless consist network (Figure 26).



a) Wired CN with wireless ED   b) Wireless CN

Figure 26 – Wireless consist network

Adoption of a wireless technology shall be selected under consideration of at least:

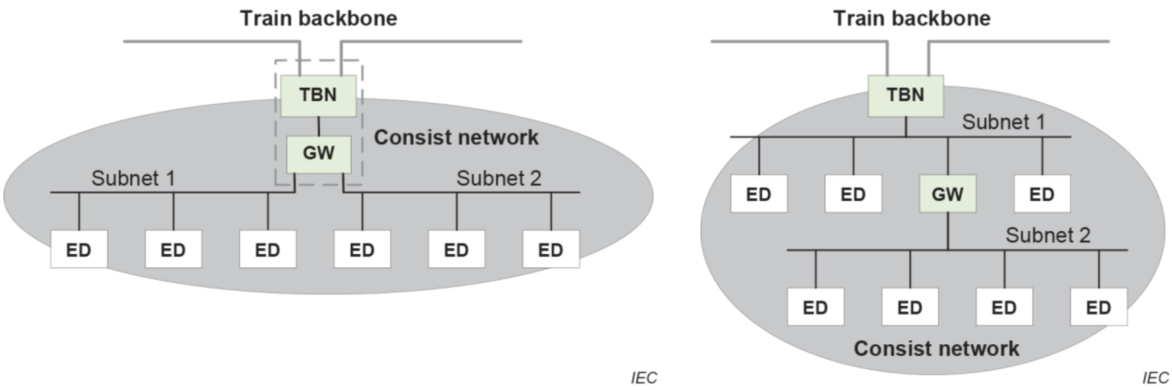
– ability to connect stationary and mobile (in motion) WED;
– limitation of the unintentional generation, propagation and reception of electromagnetic energy which can cause unwanted effects such as electromagnetic interference (EMI), physical damage in operational equipment or even harm to animate beings;
– ability to secure against cybersecurity threats coming from outside or inside the train for the risks identified in a cybersecurity risk analysis (see Clause 8).

Connection of WED to the (wired) consist network and the train backbone shall be established by a wireless access point (WAP), which at least shall provide capabilities for:

– data transfer between wired and wireless consist network;
– optional: Roaming support to provide access to WED in motion;
– cybersecurity features support, like for example:
  - WED identification and access control;
  - traffic filtering (firewall);
  - logging of cybersecurity related events.

6.3.4 Sub-networks

A consist network can be sub-structured into different sub-networks as for example depicted in Figure 27.



a) Parallel b) Serial

Figure 27 – Sub-networks in a consist network

For data exchange between consist network subnets a local gateway shall be used for a direct interconnection of the subnets (not via train backbone).

In parallel subnet architecture, train backbone node and local gateway can be combined in one network device.

EXAMPLE 1 In Ethernet based TCN, the router function inside the ETBN is used for local inter-subnet routing and ECN/ETB routing.

Dependent on the used technology, consist network subnets can be physical or virtual. Several virtual subnets can be allocated to one physical subnet, in which each virtual subnet forms its own broadcast domain.

EXAMPLE 2 In Ethernet based TCN like ETB (IEC 61375-2-5) and ECN (IEC 61375-3-4) this is implemented with Virtual LANs (VLAN) as specified in IEEE 802.1Q [1].

6.3.5 Heterogeneous consist network

The consist network can also be composed of a combination of different technologies. For instance, a consist network can 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 28.

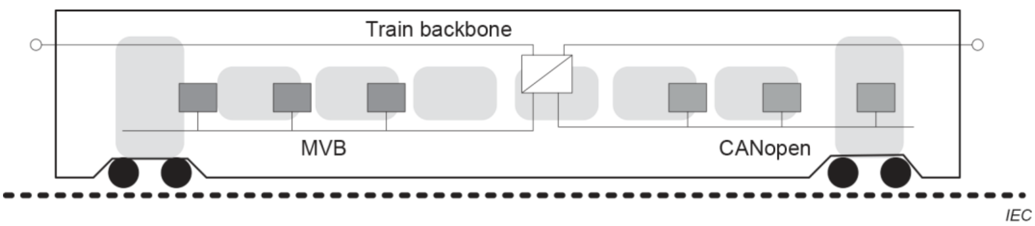


Figure 28 – Implementation example for two vehicle busses

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 document can 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 29.

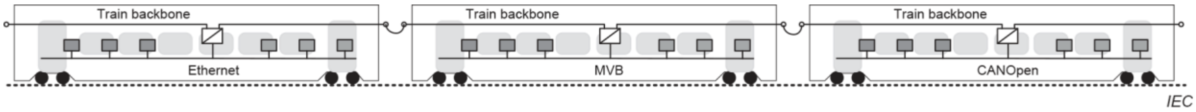


Figure 29 – Example of heterogeneous train control network architecture

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 can be implemented as either:

a) application layer gateways operating on OSI layer 7;

b) router operating on OSI layer 3;

c) bridge operating on OSI layer 2.

Homogeneous communication train backbone technology for train wide communication like WTB, WLTB or ETB should be used in order to avoid gateways between train parts using different train backbone technologies, like one part with WTB and another part with ETB only.

Train backbone and consist network can be on different cybersecurity trust levels. Gateways shall foresee cybersecurity measures necessary to protect the network of higher cybersecurity trust level against unacceptable cybersecurity risks originating from the network with lower cybersecurity trust level. Implemented cybersecurity measures shall not hamper interoperability between vehicles on train backbone level. See Clause 8 for further details.

6.4.3 Application layer gateway

Application layer gateways (ALG) interconnect the train backbone and consist network on OSI Layer 7 (application layer).

An application layer gateway should be used in the following cases:

a) for the transfer of application data between networks using different and incompatible communication protocols;

EXAMPLE 1 Process data exchange between WTB and MVB requires an application layer gateway.

b) to support enhanced cybersecurity protection for access from the TB to the CN or vice versa.

EXAMPLE 2 Application data exchange between WLCN and ETB or between WLTB and ECN.

6.4.4 Gateway implemented by a router

Routers interconnect the train backbone and the consist network on OSI Layer 3.

For using routers, the following conditions apply:

a) the transfer of application data between CN and TB uses compatible OSI Layer 3 communication protocols;

EXAMPLE 1 Message data exchange between WTB and MVB is performed by a router.

b) the usage of a router complies with cybersecurity requirements for access protection from TB to the CN or vice versa:

   1) in case of CN and TB are on equal cybersecurity ‘trust’ level, no additional measures are needed;

   2) in case of CN and TB are not on equal cybersecurity ‘trust’ level, packet filtering (firewall) shall be applied.

EXAMPLE 2 ECN connected with ETB via an IP router. No IP packet filtering required if both ECN and ETB are on equal cybersecurity ‘trust’ level.

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 device.

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

In consists with multiple consist networks of same technology, one router device can be used to connect the consist networks with the train backbone.

In trains with multiple train backbones of same technology, one router device can be used to connect the train backbones with the consist network(s).

EXAMPLE 3 Multiple VLANs sharing one physical ETB.

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).

6.4.5 Gateway implemented by a bridge

Bridges interconnect the train backbone and the consist network on OSI Layer 2. As bridges between TB and CN violate the principle of a two-level architecture as pointed out in 4.3.1, bridges may only be used in exceptional cases.

For using bridged connections, the following conditions apply:

a) the transfer of application data between CN and TB uses compatible OSI Layer 2 communication protocols;

EXAMPLE Data exchange using Ethernet as defined in IEC 61375-2-5 and IEC 61375-3-4.

b) CN and TB are on the same cybersecurity trust level.

7 On-board data communication

7.1 General

Clause 7 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 **their location** 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 Unknown 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 need not know how many data sinks are available. Location 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 30.

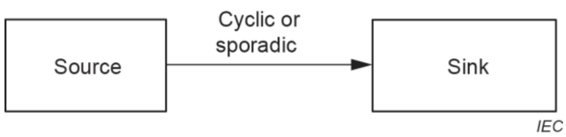


Figure 30 – Point to point communication pattern (push)

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

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 31.

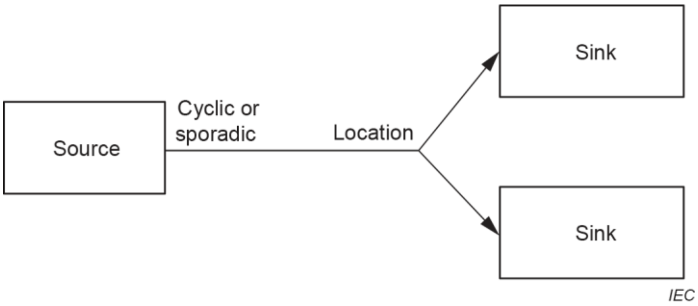


Figure 31 – Point to multi-point communication pattern (push)

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

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 32.

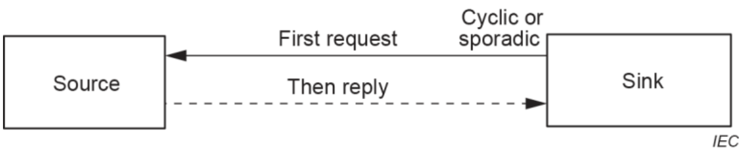


Figure 32 – Point to point communication pattern (pull)

Pull – Point to Point	
Data sending	Cyclic or sporadic.
Destination	1 case only: sink knows source.
Acknowledgement	3 cases: – cyclic without acknowledgement – sporadic with acknowledgement – sporadic without acknowledgement Reply can replace/include the acknowledgement for the request. With or without acknowledgement 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 33.

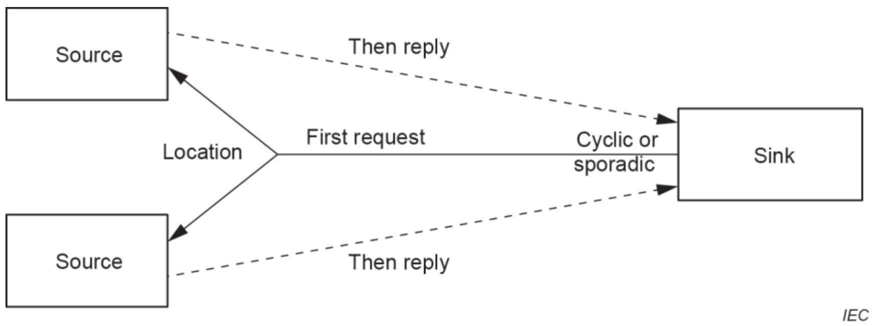


Figure 33 – Point to multi-point communication pattern (push)

Pull – Point to Multi-Point	
Data sending	cyclic or sporadic.
Destination	2 cases: – sink knows sources. – sink does not know the source but the location, and targeted sources replies.
Acknowledgement	3 cases: – cyclic without acknowledgement – sporadic without acknowledgement – sporadic on first acknowledgement (other acknowledgements are ignored) – sporadic on all acknowledgements Reply can replace/include the acknowledgement (from source to sink) With or without acknowledgement for reply (from sink to source).

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 34.

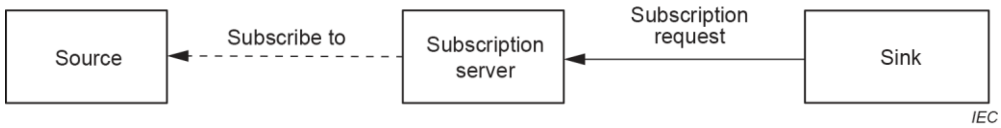


Figure 34 – Subscription communication pattern

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 can have identical consist network addresses. This can be used to manufacture identical consists.

The consist network address should 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 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 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 can 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).[3]

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

7.3.2.3 Group addresses

Communication devices can 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 can 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 train to ground communication gateway 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 1 Communication devices sending to communication devices located in another consist network of the same consist or located in the same closed train can, 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 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 can be used as a destination address of a communication device located in the same consist network.

NOTE 2 The last requirement expresses the possibility to address a consist network local communication device with the train network address, which can 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.

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 [3] defines the tuples [source_consist;source_function] and [destination_consist;destination_function] for application addressing.

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, have to provide a service which maps, transparently to the user, the function name to the related source or destination network address.

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

A function name can also be represented by a number.

NOTE The advantage of functional addressing is that a sending user application needs not to 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, can be interrupted during train inauguration for the duration of the train inauguration.

7.5 Data classes

7.5.1 General

This subclause specifies the data classes which should be supported by the different consist network technologies and train backbone technologies defined in this document.

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 (net) data rate. Measuring unit: bit/s, kbit/s, Mbit/s, Gbit/s
Cycle time	Time interval between two data packets sending, for cyclically transmitted data. Measuring unit: milliseconds (ms), seconds (s)
Latency	Transmission time of the data packet from data source (emission time) to data sink (reception time). Measuring unit: milliseconds (ms), seconds (s)
Jitter	Variance in network traversal time for subsequent data packet issued from a given source to a given sink. Measuring unit: milliseconds (ms), seconds (s)
Data integrity	Application data packet shall be received uncorrupted by the sink. Measuring units: bit error rate (BER), frame error rate (FER), packet error rate (PER)
Safety integrity	Capability of the overall system to detect and negate hazardous fault which could result from: – data corruption; – sequencing error (unintended repetition, wrong sequence); – insertion; – timely delivery error; – authentication error (wrong source, wrong destination, wrong usage allocation). Measuring unit: Hazardous failure rate (HFR) NOTE HFR is defined in IEC 62280 [8]
Security level	Measure of level of security in place that the train communication system is sufficiently protected against the threat of (cybersecurity) attacks, and functions in the intended manner. Aspects to be considered are availability, integrity, confidentiality, authenticity through the 7 foundational requirements of the security level vector: a) Identification and authentication control (IAC), b) Use control (UC), c) System integrity (SI), d) Data confidentiality (DC), e) Restricted data flow (RDF), f) Timely response to events (TRE), g) Resource availability (RA). Measuring unit: security level target (SL-T) as defined by IEC 62443-3-3:2019. NOTE 1 In IEC 62443-3-3:2019 SL-T is expressed as a vector. NOTE 2 Management of cybersecurity is in general presented in Clause 8.

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

data rate:	64 kbit/s
latency:	< 100 ms
jitter:	< 30 ms
data integrity:	< 10^{-3} BER

EXAMPLE 2 Sending cyclically a control message to the brake controller, which is defined with the subsequently listed service parameters. For cybersecurity it is assumed that for all integrity aspects and for availability a high protection is needed, while confidentiality needs less protection.

data packet size:	64 bit
cycle time:	100 ms
latency:	< 100 ms
jitter:	< 10 ms
data integrity	< 10^{-6} BER
safety integrity:	HFR < 10^{-7}/h
SL-T	{3,3,3,1,3,3,3}

7.5.3 TCN data class definition

For TCN five principal data classes are defined (see Table 7). Table 7 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 the IEC 61375 series. 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.

Data class	Description/ Main characteristics
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;
- and more generally all flows on OMTS.

7.6 Communication profile

A communication profile can be defined for specific application fields which rules how to use the communication technologies defined in this document for the specific purpose of this application.

The communication profile shall:

a) select the network technologies for the train backbone or the consist network which the communication profile shall be based on (e.g. WTB or ETB);
b) define the network application field (like open trains, closed trains);
c) define an application addressing scheme and the mapping to the addressing scheme provided by the selected communication technology. An application addressing scheme is 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. However 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, such as addressing the leading consist 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 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 [3].

7.7 Application profile

An application profile can be defined for specific application fields which defines the application services and the related application data exchanged.

EXAMPLE An application profile for international passenger trains has been defined by UIC in the UIC Code 556 [3]. This application profiles defines the train wide control of doors, lighting, brakes, propulsion, and HVAC.

8 Cybersecurity

8.1 General

The cybersecurity aspects for the TCN, its subsystems and lifecycle aspects for system using them are covered by both horizontal and railway standards. The IEC has been developing the IEC 62443 series [9] to cover common requirements and aspects of cybersecurity in industrial automation system in general, also applicable at railway application, system, and component levels. The IEC is working on the new standard IEC 63452 Railway applications – Cybersecurity, providing guidance and requirements on the cybersecurity assurance of systems under consideration during design, implementation and test phases and for security management during operation and maintenance phases.

Clause 8 defines the guidelines for TCN protocols, on a general architectural level, considering the needs of asset owners and railway undertakings to support the cybersecurity protection goals after their individual risk assessment. At the same time interoperability considerations are taken into account. Detailed protocol definitions are subject to the relevant parts of the IEC 61375 series, processual issues are beyond the scope of the IEC 61375 series.

When defining protocols, considerations are to be taken on how to deal with broken chains of trust or compromised credentials, or both. Users are advised to also consider such events and when setting up lifecycle processes, this is, however, beyond the scope of this standard.

8.2 System under consideration

For the purpose of the IEC 61375 series, the system under consideration is the Train Communication Network (TCN) comprising the train backbone and consist networks. Interfaces of the TCN are:

a) TB network interface to neighbouring consist;
b) a consist typically offers two train backbone interfaces (one at each end), though in special cases one or both may not be implemented;
c) ED-Interfaces at CN level;
d) the EDs themself are out of scope of this document;
e) type and number of the EDs connected to a CN may be defined;
f) Wayside interface;
g) the (optional) wayside interface of a TCN is offered by one or more MGC as defined in 4.5;
h) other interfaces to the wayside like, but not limited to, train radio or CCS are out of scope of this document.

Each part of the IEC 61375 series shall define the exact respective system under consideration it is covering, i.e. the CN or the TB.

8.3 Lifecycle

8.3.1 General

Lifecycle aspects are beyond the scope of this document and the IEC 61375 series but are to be considered when applying the IEC 61375 series. It is up to the users of this document, e.g. component manufacturers, system integrators, asset owners, to ensure all lifecycle aspects with respect to cybersecurity are taken care of.

8.3.2 Legacy systems

As the IEC 61375 series predates cybersecurity considerations many legacy systems based on it have not been designed with cybersecurity in mind. This needs to be addressed in projects applying the standard. Future revisions of parts of the IEC 61375 series will address those topics and migration aspects such that evolution of systems becomes possible.

8.3.3 Protocol design

When defining the communication and application protocols, cybersecurity aspects are to be considered in a way that users of the IEC 61375 series can implement projects with sufficient security for their protection goals while allowing interoperability.

Protocols will be defined such that evolution is possible and the impact of security violations can be qualified and minimized.

8.4 Guidelines

Cybersecurity measures are to be applied for inter-consist, intra-consist and consist-wayside communication.

As this standard series only deals with the train communication network, securing application layer functions and protocols is beyond the scope of this document and the IEC 61375 series, with the exception where the IEC 61375 series defines application layer protocols itself, e.g. for train inauguration.

Network traffic of different criticality may require different protection goals. Further, the communication peers of different functions may not trust each other. Network segmentation allows keeping those traffics separated unless communication relationships are explicitly established. Where network segmentation is used, gateways can be used to control traffic crossing that boundary. The gateway functions are defined according to project specific security analysis and are beyond the scope of this document. This allows functions having a legitimate necessity but are hosted on network nodes located in different networks to communicate with each other. Gateways can enable this kind of legitimate communication while blocking illegitimate traffic.

NOTE 1 Network separation is done on logical networks. The logical networks can be mapped to the same or different physical networks.

To protect the train communication network, setting up a communication link between a consist and the wayside is always initiated by a network node in consist. Network nodes in a consist reject any connection attempt on communication link level from a wayside entity. Once the communication link is established, wayside entities can initiate communication through that link.

NOTE 2 This allows a consist to select the wayside entity is best suited to communicate with, depending on the geographic position, trust, user traffic need and other reasons. It further allows the consist to protect itself against unwanted communication. As the wireless links might be unavailable for a variety of reasons, a consist needs to be designed such that operation without a link to the wayside is possible, albeit potentially with degraded functionality.

The technology specific parts of the IEC 61375 series define the protocol mechanisms to be applied for each technology.

Annex A
(informative)

High-level train architecture

A.1 General

The TCN connects various train functions and, through the train-to-ground connection, train functions and functions on the wayside. This Annex provides an overview of the high-level structure of those functions on an informative level.

It further provides examples of (on-board) network structures that can be used to address, beside other aspects, evolution and cybersecurity topics when designing or retrofitting trains.

A.2 Architectural realms

The on-board functions are associated with different realms. Architectural realms are a logical concept to structure train functions along coherent boundaries. Those boundaries can be driven by various aspects like safety aspects, security considerations, or areas of responsibility. It is important to separate those orthogonal aspects and not confuse them. The system architecture defines the realms for a given setup.

Note that a realm is not equivalent to a zone, which is a security concept. A realm also is not equivalent to a domain as domains in a domain structure can overlap while realms provide a clear separation which is typically driven by the domain structure.

Realms can be cascaded in a hierarchical manner where necessary.

Figure A.1 provides an example of a possible realm structure in a train and their communication relations. It also shows some wayside realms to provide a more complete overview, as functions therein interact with the train functions through the train to ground communication specified in IEC 61375-2-6. Note that the example does not address separation of responsibilities.

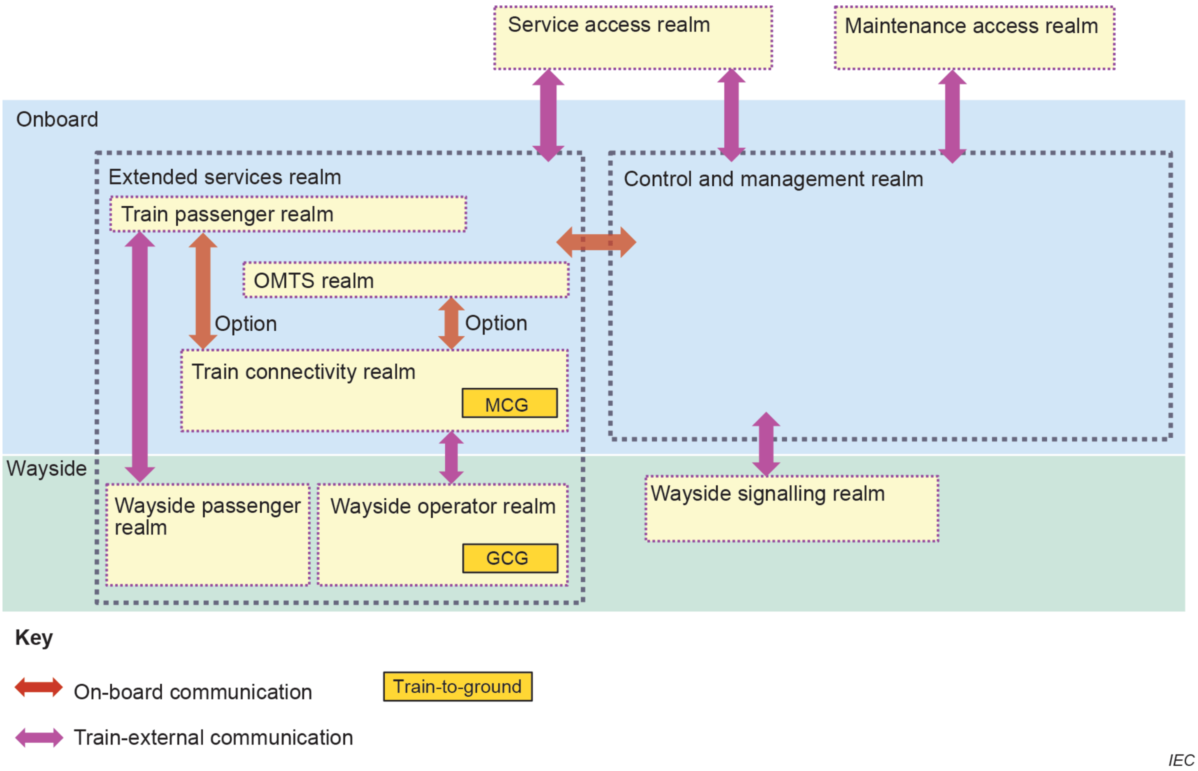


Figure A.1 – Example of architectural realm structure

The "Control and management realm" is strictly limited to train on-board aspects and comprises on-board safety functions, including TCMS and automatic train operation and protection (which can be part of a separate realm in other architectures). Some examples for functions provided are traction, brake, external doors, exterior lighting, and train control functions including the HMI and diagnostics. It can further comprise services like process data handling, SW management, authentication and authorisation. A significant part of the functions and services in this realm have at least some homologation relevance. The communication between on-board safety functions inside this realm and the function of the gateway towards the other realms are subject to the IEC 61375 series. Functions in this realm can interact with wayside functions through the train-to-ground communication defined in IEC 61375-2-6.

The "Extended services realm" provides additional functions and services and expands to the wayside. In this example, it is hierarchically split into several realms on its own. The train connectivity realm provides the on-board service for managing the operational communication with the wayside (Note: Signalling and train passenger related communication, which are not the subject of this document or the IEC 61375 series, often use other means of communication). The Mobile Communication Gateway (MCG) is defined in IEC 61375-2-6. The Telematic and multimedia realm (not to be confused with the OMTS domain) provides non-safety relevant functions like passenger information, video surveillance, passenger counting, catering, toilets, ambient lighting, and others. In that realm, additional services can be present, complementing the services offered by the control and management realm, e.g. to facilitate evolution of those services. While some functions from the OMTS domain, realized in the telematic and multimedia realm, can have homologation relevance, e.g. font size on passenger information displays, they are independent from homologation-relevant topics in other realms (e.g. maximum tractive effort).

The "Train passenger realm" comprises services accessible directly by the passengers like passenger WiFi or entertainment systems. Those services often feature their own connectivity to the wayside but can also use the services provided by the train connectivity realm, depending on the realization. OMTS and train passenger functions are subject to the IEC 62580 series [4].

On-board functions from both the control and management realm as well as from the extended services realm can have supporting/controlling functions in wayside realms. Wayside functions are not in the scope of this document.

The maintenance access realm and service access realms offer access to maintenance and service of on-board systems and functions.

Besides the structure described here, other structures are also possible, e.g. structured along areas of responsibility. Note that the internal structure of the realms can vary.

A.3 On-board network structures

Various network configurations, both on train backbone and consist network level, are possible to support the defined realms. The selection of a configuration can be different between the train backbone and consist network level. Drivers for selecting a configuration can be responsibility, cybersecurity and evolvability aspects.

In Figure A.2 three different possibilities for physical network setups (A, B and C) are shown as an example, assuming a realm structure similar to the description in Clause A.2. Other or more detailed splits not shown in this example are also possible, e.g. to segregate along areas of responsibility. Note that this figure and the description below are applicable to both train backbone and consist network level independently. The two levels as well as independent consists within a train may be implemented in different ways. To support coupling of consists on network level, the structures on train backbone shall match for all consists.

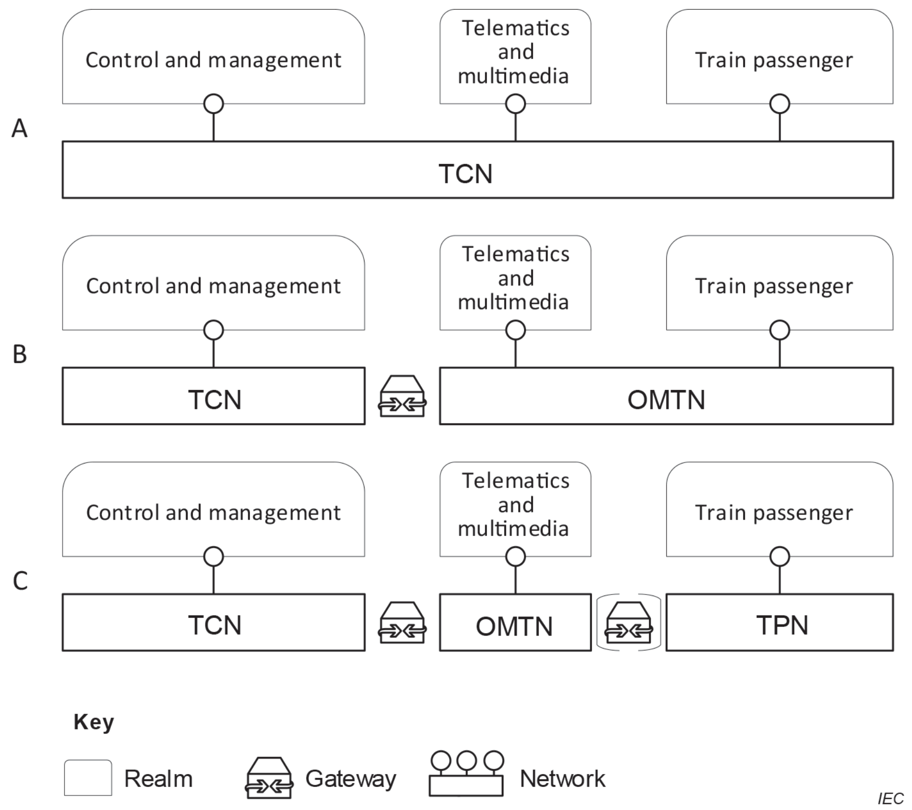


Figure A.2 – Examples for network segregation of on-board physical networks

Gateways are shown only between the physically segregated networks. Further gateways can be used to further separate the realms internally. Additional physical networks can be introduced provided the necessary communication paths between end devices can be established. As indicated by the brackets, the gateway between OMTN and TPN is optional and would not be present in case the TPN is to be completely isolated from the TCN and OMTN. Gateways can be bi- or unidirectional.

– **Example A** features a single physical common onboard network where all systems are connected. Segregation between the realms is achieved by use of virtual networks with gateway functions between them.
– **Example B** segregates the control and management realm to its own physical network, while the complete extended services realm shares a common physical network. The sub-realms of the extended services realm are segregated through virtual networks. Data exchange between the networks, both physically and virtually segregated, is possible through gateway functions. As described before, gateways between logically segregated networks are not shown in the figure.
– **Example C** segregates the control and management realm, the telematics and multimedia realm and the train passenger realm to own physical networks. Train connectivity can be realized in any single or even in multiple networks, depending on cybersecurity and other considerations. Data exchange between the networks, both physically and virtually segregated, is possible through gateway functions, where present. The gateway between the TPN and OMTN is optional and may be omitted if the TPN is to be completely isolated.

Examples B and C provide physical segregation of safety-relevant functions (in the command and management realm) from functions with high evolution rates, allowing for easier homologation and evolution without (high) impact to safety aspects. All relevant safety aspects are to be fully encapsulated in the common onboard network. This allows reconfiguring of the OMTN and TPN without impacting the TCN, thereby easing homologation of changes.

Further segregation into virtual networks and the gateway functions between those networks are subject to operational needs and to cybersecurity analysis. When segregating networks physically or logically and defining the gateway functions, the necessary communication relations between end devices throughout the train need to be considered.

This structure does not preclude additional on-board networks e.g. dedicated analogue networks for audio intercom or multiple physical OMTN/TPN instances.

Bibliography

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[10] IEC 62443-3-2:2020, *Security for industrial automation and control systems - Part 3-2: Security risk assessment for system design*