# D2.1 – Requirements of LTE Equipment and ETBNs for wireless TCMS

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| **Abstract:** | In this report, we address the requirements of LTE equipment for integration in train backbone and ETBNs in order to deal with wireless train inauguration. |
| **Keywords:** | D2D, ECN, ETB, LTE, LTE ProSe, Requirements, TCMS, WLTB. |

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# Executive Summary

Deliverable *D2.1 - Requirements of LTE Equipment and ETBNs for wireless TCMS* - defines the requirements of the devices needed to build a Wireless Train Backbone in order to perform a wireless inauguration of the train. These devices will include LTE radio equipment and modified railway ETBNs. The analysis has been done in close collaboration with the complementary project CONNECTA-2. The obtained requirements will be used as a baseline for subsequent tasks in WP2 of Safe4RAIL-2 which are related to the design and implementation of the WLTB devices, the interoperability tests for wireless train inauguration, and performance of the WLTB in demanding scenarios. On the other hand, those requirements related to Drive-by-Data will be re-analysed in Task 2.6 (“DbD concept evolution towards wireless Train Backbone”).

# Contents

# List of Tables

# Chapter 1 Introduction

## 1.1 Scope

In the scope of Safe4Rail-2 WP2 activities, the requirements demanded for a Wireless Train Backbone Node (WLTBN) are described in the present document. As can be observed in Figure 1, a WLTBN is formed by an Adapted ETBN (AETBN), which is connected to the Ethernet Consist Network (ECN), and a Radio Device (RD), in this case LTE equipment, which is connected to the Wireless Train Backbone (WLTB).

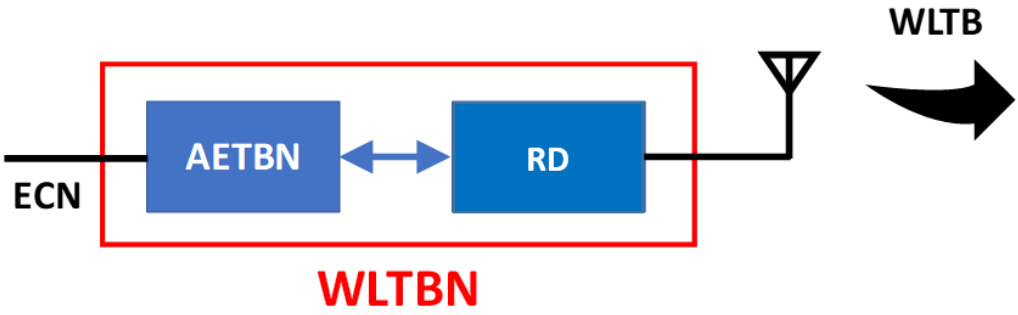


Figure 1: WLTBN Architecture

Chapter 2 of this deliverable will detail the requirements of the RD, while Chapter 3 will detail those of the AETBN. These requirements have been defined in close collaboration with the partners of the complementary project CONNECTA-2, and they have been written according to the naming rules defined in Chapter 2 of Deliverable D1.1 “Drive-by-Data Requirements Specification”.

## 1.2 Definitions

The table below contains some definitions of the terms presented in the requirements, in order to ease the understanding of the requirements and to avoid and clarify any confusion that might arise.

| Term | Definition |
|---|---|
| Firewall | Software used to maintain the security of a private network. Firewalls block unauthorized access to or from private networks. |
| LTE ProSe | Device to device technology which allows LTE devices to detect each other and to communicate directly. |
| LTE-D2D | Mode of communication mainly intended for emergency services and other similar applications that allow two LTE devices to communicate directly with each other without the necessity of a base station. |
| LTE-V2X | Mode of communication which enables LTE devices the data exchange between a vehicle and its surroundings. |

Table 1: List of Definitions

# Chapter 2 Requirements for RDs

This chapter describes the requirements of the LTE equipment suitable for WLTB. The structure of the chapter has been divided in *High Level Requirements* provided by the demonstrator and *Detailed Level Requirements* for the WLTB devices. The requirements have been structured in tables, containing the following fields:

- Req ID (Requirement Identificator): *High Level Requirements* have been named according to the original requirement identificator coming CONNECTA-2. For naming Detailed Requirements, *WLTB* has been used as "systemacronym" and *RD (Radio Device)* as "device/demoacronym"
- Description: description of the requirement
- Relevant for Demonstrator (Yes/No): indicates whether a requirement is relevant or not for a RD to be integrated in the CONNECTA-2/Safe4RAIL-2 demonstrator. This field has been included in the *Detailed Requirements*.
- Safety Related (Yes/No): indicates whether a requirement is safety related or not. This field has been included in the *Detailed Requirements*.
- Source: indicates which CONNECTA or CONNECTA-2 requirement is the source of the requirement.
- Notes: additional observations on the requirement.

## 2.1 High Level Requirements for Demonstrator

### *2.1.1 General requirements*

| Req ID | Requirement | Requirement Source |
|---|---|---|
| CTA2-D1.1-1102 | The WLTB radio device shall create a WLTB communication network between all WLTBN participating in the train composition. | CTA-D1.5-26<br>CTA-D3.1-01 |
| CTA2-D1.1-1103 | The WLTB radio device shall be able to communicate with other WLTBNs out of its radio coverage by implementing a multihop data forwarding protocol. | CTA-D1.5-35<br>CTA-D3.1-47 |
| CTA2-D1.1-1108 | The WLTB devices shall be compliant with the IEC 62443. | CTA-D1.5-33<br>CTA-D1.5-34<br>CTA-D3.1-58<br>CTA-D3.1-59 |
| CTA2-D1.1-1111 | The bandwidth of the wireless TCMS shall be limited to 70% of its maximum. | CTA-D1.5-39 |
| CTA2-D1.1-1215 | The radio WTLB Device shall fulfil the laws guaranteeing against its impact on the staff and on the passengers. Wireless TCMS devices shall be compliant with the European directive RED 2014/53/EU. Wireless TCMS devices shall be compliant with the norm EN 62311:2008. | CTA-D1.5-30 |

Table 2: General requirements (high level requirements)

### *2.1.2*

### *2.1.3 Communication requirements*

| Req ID | Requirement | Requirement Source |
|---|---|---|
| CTA2-D1.1-1301 | Only WLTBN of the coupling group should be able to communicate each other, excluding messages coming from other sources. | --- |
| CTA2-D1.1-1302 | WLTBN shall be able to discover adjacent WLTBNs. | --- |
| CTA2-D1.1-1303 | WLTBN of the same WLTB (i.e. excluding WLTBN from other train units) should be able to create a local forwarding table for the WLTBNs which are not reachable with a single hop. | --- |
| CTA2-D1.1-1304 | Redundant WLTBN devices shall be able to work in different frequencies in order to avoid single point failures in a single band. | CTA-D3.1-48 |
| CTA2-D1.1-1305 | The WLTBN should be designed to allow frequency reutilization when possible. | --- |
| CTA2-D1.1-1306 | The WLTB radio device shall ensure that the maximum time for the permitted interruption remains below 1.0s. | CTA-D3.1-50 |

Table 3: Communication requirements (high level requirements)

### 2.1.4 Configuration requirements

| Req ID | Requirement | Requirement Source |
|---|---|---|
| CTA2-D1.1-1401 | The WLTB radio shall be able to load a certificate or shared key for group authentication/authorization and secure data communication (related to CTA2-D1.1-1301). | --- |
| CTA2-D1.1-1402 | Static IP addresses of the ETBN shall be set in the ECN interface. | --- |
| CTA2-D1.1-1403 | When DHCP is available for dynamic IP addressing and the ECSP is located within the ETBN, the DHCP server shall be configured. | --- |
| CTA2-D1.1-1404 | When ECSP is located within the ETBN, the static consist information shall be configured. | --- |
| CTA2-D1.1-1405 | ETB Inauguration (TTDP) settings: Settings required for the ETBN to conduct ETB inauguration according to IEC 61375-2-5. | --- |
| CTA2-D1.1-1406 | Settings required for the ETBN to act as firewall. | --- |

Table 4: Configuration requirements (high level requirements)

### 2.1.5 Logging requirements

| Req ID | Requirement | Requirement Source |
|---|---|---|
| CTA2-D1.1-1501 | The WLTBN devices shall support logging of OS related events. | --- |
| CTA2-D1.1-1502 | The WLTBN shall support logging of neighbour discovery process. | --- |
| CTA2-D1.1-1503 | The WLTBN shall support logging of failure authentication/authorization attempts in neighbour discovery process. | --- |

Table 5: Logging requirements (high level requirements)

### 2.1.6 Network requirements

| Req ID | Requirement | Requirement Source |
|---|---|---|
| CTA2-D1.1-1702 | The WLTBN radio device shall act as an OSI L2 bridge between the WLTB and the WLTBN AETBN. | CTA-D3.1-06<br>CTA-D3.1-08 |
| CTA2-D1.1-1715 | The WLTBN shall support DHCP server to provide IPv4 address allocation as defined in RFC 2131 Clause 3. | CTA-D3.1-07 |

Table 6: Network requirements (high level requirements)

### 2.1.7 Time requirements

| Req ID | Requirement | Requirement Source |
|---|---|---|
| CTA2-D1.1-1801 | The WLTBN shall support precise time synchronization based on GNSS/Ground Infrastructure. | --- |
| CTA2-D1.1-1802 | The WLTBN of the leading consist should be able to act as a clock reference for the rest of WLTB devices. | --- |
| CTA2-D1.1-1803 | The WLTB radio device shall be able to propagate clock synchronization to the ECN via IEEE 1588 with a precision<br>of ≤ 10 µs with a jitter of ± 1 µs (consist level)<br>of ≤ 20 µs with a jitter of ± 2 µs (train level)<br><br>Note: The suitability of these accuracy values will be evaluated by Safe4RAIL-2 T2.6 and the results will be publicly available in Safe4RAIL-2 D2.4. | CTA-D3.1-16<br>CTA-D3.1-17<br>CTA-D3.1-31 |
| CTA2-D1.1-1804 | Setup of synchronized clock after startup or network reconfiguration (e.g. inauguration) should be limited to 1.0s | CTA-D3.1-18 |

Table 7: Time requirements (high level requirements)

## 2.2 Detailed requirements

### *2.2.1 General requirements*

| Id | Description | Relevant for Demonstrator | Safety related | Source | Notes |
|---|---|---|---|---|---|
| WLTB-RD-001 | The radio WLTB maximum TX power should follow the limits indicated in ETSI EN 302 571 | Yes | No | CTA2-D1.1-1215 | |
| WLTB-RD-002 | The WLTB radio device shall implement SNMP with specific MIB to indicate the following data in real time:<br>• Status of the device<br>• Status of the radio link (e.g. SNR, BER)<br>• Number of detected neighbours<br>• List of neighbours (e.g. unique ID)<br>• List of lost neighbours (i.e. since inauguration) | Yes | No | CTA2-D1.1-1110 | |
| WLTB-RD-003 | The WLTB radio shall implement a mapping between the EC61375-1 and TS 23.203 Rel-14 QoS classes. | Yes | Yes | CTA2-D1.1-1113 | |

Table 8: General requirements (detailed requirements)

### *2.2.2 Communication requirements*

CONNECTA-2 is requesting IPv4 support (see CTA2-D1.1-1715). Therefore, IPv4 will be used instead of IPv6.

| Id | Description | Relevant for Demonstrator | Safety related | Source | Notes |
|---|---|---|---|---|---|
| WLTB-RD-004 | LTE ProSe device should support Consist-based Group Communication | Yes | No | CTA2-D1.1-1301 | LTE-D2D rel. 14 supports group-based communication (ProSe), but not LTE-V2X.As a consequence: we need to use LTE-D2D to match this requirement. |
| WLTB-RD-005 | LTE ProSe device should support Neighbour (Consist) Discovery | Yes | No | CTA2-D1.1-1302 | LTE-D2D rel. 14 supports neighbour discovery (ProSe), but not LTE-V2X. As a consequence: we need to use LTE-D2D to match this requirement. |
| WLTB-RD-006 | LTE-ProSe Service should support IETF MANET RFC stateful protocols | Yes | No | CTA2-D1.1-1303 | |
| WLTB-RD-007 | LTE-V2X device should support two Frequency bands for redundant communications (ITS + else) | Yes | Yes | CTA2-D1.1-1304 | LTE-V2X should operate by standard in ITS bands, but it could also operate in other unoccupied sub-6-GHz ISM bands. |
| WLTB-RD-008 | LTE Prose device should support frequency reuse through at least 3 different RB Pools within the ProSe Frequency band (central, left and right consists) | Yes | No | CTA2-D1.1-1305 | LTE-D2D/V2X allows multiple RB-pools; in ad-hoc mode, the pools are hard coded; in mode 3, the eNB announces the pools. The spectrum will be configured with the number of RB-pools corresponding to the number of frequency reuse. |

| Id | Description | Relevant for Demonstrator | Safety related | Source | Notes |
|---|---|---|---|---|---|
| WLTB-RD-009 | LTE Prose Service should be agnostic of the multi-RB Pools (should manage multiple group communications) | Yes | No | CTA2-D1.1-1305 | LTE-D2D/V2X RB-details are specific per group/service. IP-routing should be linked to the ProSe Service. An adaptation layer will be required to match this requirement. |
| WLTB-RD-010 | LTE Prose device resource reallocation should be limited to 1s | Yes | Yes | CTA2-D1.1-1306 | LTE-D2D reallocation depend on the scheduler; in LTE-V2X, it is 100ms. |
| WLTB-RD-011 | LTE-V2X should support broadcast, multicast and unicast communications | Yes | Yes | CTA2-D1.1-1102<br>CTA2-D1.1-1301<br>CTA2-D1.1-1302<br>CTA2-D1.1-1303 | LTE-V2X rel.14 is restricted to broadcast (stateless); unicast and multicast will be supported with an overlay. |
| WLTB-RD-012 | LTE-V2X SPS scheduler with guaranteed delay | Yes | Yes | CTA2-D1.1-1306 | LTE-V2X rel. 14 mode 4 scheduler does not provide guaranteed delay. The semi-persistent scheduler provides some-kind of delay guarantee, but does not avoid collisions. A new LTE-V2X scheduler is required to match this requirement. |
| WLTB-RD-013 | LTE Prose device should be able to operate in ad-hoc mode | Yes | Yes | CTA2-D1.1-1301<br>CTA2-D1.1-1102 | LTE-V2X rel. 14 mode 4 operates in ad-hoc mode. LTE-V2X rel. 14 shall be used to match this requirement. |

Table 9: Communication requirements (detailed requirements)

### 2.2.3 Configuration requirements

| Id | Description | Relevant for Demonstrator | Safety related | Source | Notes |
|---|---|---|---|---|---|
| WLTB-RD-014 | The WLTB radio shall be able to load a certificate or shared key for group authentication/authorization and secure data communication | Yes | Yes | CTA2-D1.1-1401 | Will add key management in default configuration |
| WLTB-RD-015 | The WLTB radio shall include a DHCP v4 server; it should yield the DHCP role to the leading consist in a multi-consist train configuration | Yes | Yes | CTA2-D1.1-1403 | |
| WLTB-RD-016 | The WLTB radio shall be able to load the multi-RB pools for multi-frequency resource allocation | Yes | Yes | CTA2-D1.1-1305 | Done by default in LTE-V2X mode 4 |
| WLTB-RD-017 | The WLTB radio shall be able to load the internal location of each RB pool | Yes | Yes | --- | Done by default in LTE-V2X mode 4 |

Table 10: Configuration requirements (detailed requirements)

### 2.2.4 Logging requirements

| Id | Description | Relevant for Demonstrator | Safety related | Source | Notes |
|---|---|---|---|---|---|
| WLTB-RD-018 | The WLTBN devices shall support logging of OS related events. | Yes | No | CTA2-D1.1-1501 | |
| WLTB-RD-019 | The WLTB radio device shall support logging of neighbour discovery process (received "Hello" messages). | Yes | No | CTA2-D1.1-1502 | |
| WLTB-RD-020 | The WLTB radio device shall support logging of failure authentication/authorization attempts in neighbour discovery process. | No | Yes | CTA2-D1.1-1503 | |

Table 11: Logging requirements (detailed requirements)

### *2.2.5 Network requirements*

| Id | Description | Relevant for Demonstrator | Safety related | Source | Notes |
|---|---|---|---|---|---|
| WLTB-RD-021 | The WLTB radio shall be connected to the ETBN via an ethernet connection via a bridge configuration | Yes | No | CTA2-D1.1-1702 | |
| WLTB-RD-022 | The WLTB radio shall support IP, ARP, UDP, TCP, ICMP type of communications | Yes | No | CTA2-D1.1-1704<br>CTA2-D1.1-1705<br>CTA2-D1.1-1706<br>CTA2-D1.1-1707<br>CTA2-D1.1-1708 | |
| WLTB-RD-023 | The WLTB radio shall reach the ETBN for DHCP to configure its own IP address | Yes | No | CTA2-D1.1-1715 | |
| WLTB-RD-024 | The WLTB radio shall operate as an IP router for inter-consist communication | Yes | No | CTA2-D1.1-1303<br>CTA2-D1.1-1727 | |

Table 12: Network requirements (detailed requirements)

### 2.2.6 Security requirements

| Id | Description | Relevant for Demonstrator | Safety related | Source | Notes |
|---|---|---|---|---|---|
| WLTB-RD-025 | The WLTB Radio should be able to operate without a SIM card. | Yes | No | | |
| WLTB-RD-026 | The WLTB Radio shall support IPsec in Tunnel mode for secured inter-consist communications. | No | Yes | CTA2-D1.1-1401 | |

Table 13: Security requirements (detailed requirements)

### 2.2.7 Time requirements

| Id | Description | Relevant for Demonstrator | Safety related | Source | Notes |
|---|---|---|---|---|---|
| WLTB-RD-027 | The WLTB radio devices should be synchronized with GNSS | Yes | Yes | CTA2-D1.1-1801 | The WLTB radio device will have two time references: the LTE time reference and the AETBN time reference. |
| WLTB-RD-028 | The WLTB radio devices shall use Group Time Synchronization Function | Yes | No | CTA2-D1.1-1802 | Only refers to the AETBN time reference of the WLTB RD. |
| WLTB-RD-029 | The set-up time to get a time fix (from GPS) + establishing PTP should be limited to 1s | Yes | Yes | CTA2-D1.1-1804 | With the LTE-V2X scheduler, which has a 50ms delay budget per hop, this requirement would be achievable for 20 hops (not considering collisions). |

Table 14: Time requirements (detailed requirements)

# Chapter 3 Requirements for AETBNs

This chapter describes the requirements of the AETBNs suitable for the WLTB. For this purpose, requirements for Drive-by-Data ETBNs from D1.1 [1] have been taken as a baseline, and consequently the chapter has been structured according to the sections defined for DbD ETBNs in [1]. The requirements have been structured in tables, containing the following fields:

- Type: represents the type of requirement, according to the following color coding:
  - *Requirement:* these are requirements coming directly from D1.1 [1].
  - *Modified Requirement:* these are requirements from D1.1 which have suffered some modification. The modified text has been highlighted.
  - *New Requirement:* these are new requirements that have been defined considering the wireless inauguration procedure described in [2].
- Req ID (Requirement Identificator): *Requirements* and *Modified Requirements* have been named according to the original requirement identificator coming from [1]. For naming the *New Requirements*, *WLTB* has been used as "systemacronym" and *AETBN* as "device/demoacronym"
- Description: description of the requirement
- Prod. (Y/N): indicates whether a requirement is relevant or not for an AETBN product.
- Dem.: indicates whether a requirement is relevant or not for an ETBN to be integrated in the CONNECTA-2/Safe4RAIL-2 demonstrator.
- Notes: additional observations on the requirement.

## 3.1 Network Device - Requirements from CONNECTA-2

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_001 | The ETBN shall provide at least 3 Ethernet ports following IEEE 802.3 with<br>· 2 ports GbE for ETB connection<br>· 1 port GbE for ECN connection | Y | X | 2 ETB connections for the wireless module (LTE, WIFI,…). For the demonstrator 100Mbps would be enough for AETBN. |
| *Requirement* | DBD_ND_002 | The ND ports shall support the reception and transmission of Ethernet frames in accordance to IEEE 802.3 | Y | X | |
| *Requirement* | DBD_ND_003 | The ND shall support clock synchronization in accordance to IEEE 802.1AS-rev | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_004 | The ETBN shall provide master clock for train (GlobalMC) and for ECN (ConsistMC) | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_005 | The ETBN shall provide gateway functionality for TSN and time information | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_006 | The ETBN shall support adding, recognizing, interpreting, and removing VLAN tags as defined in IEEE 802.1Q. | Y | X | |
| *Requirement* | DBD_ND_007 | The ETBN shall provide 8 output queues per port, each allocated to one traffic class 1..8. | Y | X | |
| *Requirement* | DBD_ND_008 | The ETBN shall support strict priority-based transmission selection algorithm (IEEE 802.1Q) | Y | X | |
| *Requirement* | DBD_ND_009 | The ETBN may support credit-based shaper algorithm (IEEE 802.1Q) to reduce bursts for conventional data traffic | N | | |
| *Requirement* | DBD_ND_010 | The ETBN shall support scheduled traffic in accordance to IEEE 802.1Qbv | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_011 | The ETBN shall support per stream filtering and policing as defined in IEEE 802.1Qci | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_012 | The ETBN shall act as a router between ECN and ETB for unicast and multicast IP packets including network address translation | Y | X | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_013 | The ETBN shall support the Internet protocol suite including<br>· IP (RFC 791)<br>· ARP (RFC 826)<br>· UDP (RFC 768)<br>· TCP (RFC 793)<br>· ICMP (RFC 792) | Y | X | |
| *Requirement* | DBD_ND_014 | The ETBN shall support TRDP according IEC 61375-2-3 | Y | X | |
| *Requirement* | DBD_ND_015 | The ETBN shall support SDTv4 according IEC 61375-2-3 | Y | | |
| *Modified Requirement* | DBD_ND_016 | The ETBN shall provide train backbone topology discovery according IEC 61375-2-5 with modifications defined in [2] | Y | X | |
| *Modified Requirement* | DBD_ND_017 | The ETBN shall provide train composition discovery according IEC 61375-2-3 with modifications defined in [2] | Y | X | |
| *Requirement* | DBD_ND_018 | The ETBN may support sleep mode according IEC 61375-2-3 | Y | | |
| *Modified Requirement* | DBD_ND_019 | The ETBN shall implement an ECSP according IEC 61375-2-3 with modifications defined in [2] | Y | X | |
| *Requirement* | DBD_ND_020 | The ETBN shall implement a TTDB which is managed by a TTDB Manager function | Y | X | |
| *Requirement* | DBD_ND_021 | The ETBN shall support resolving TCN-URI addresses (IEC 61375-2-3) to IP addresses | Y | X | |
| *Modified Requirement* | DBD_ND_022 | The ETBN shall provide service interfaces according IEC 61375-2-3 annex E:<br>· ECSP interface<br>· TTDB manager interface (ECSP and ED)<br>· DNS server interface (Standard & TCN)<br>· ETBN control interface | Y | X | In order to be able to retrieve the TTDB from one WLTBN to another. |
| *Requirement* | DBD_ND_023 | The ETBN shall support IGMP snooping | Y | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_024 | The ETBN should support a DHCP server | Y | | |
| *Requirement* | DBD_ND_025 | The ETBN shall support SNMP. | Y | | |
| *Requirement* | DBD_ND_026 | The ETBN may provide an authentication server (IEEE 802.1x). | Y | | |
| *Requirement* | DBD_ND_027 | The ETBN shall support detection and reporting of security events | Y | | |
| *Requirement* | DBD_ND_028 | The ETBN shall support device redundancy with switch-over time of ≤ 0.8 s. | Y | X | Redundancy will be used in Phases 3-4 of the demonstrator. |

Table 15: Network Device - Requirements from CONNECTA-2

## 3.2 Network Level Inauguration Requirements

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Modified Requirement* | DBD_ND_029 | NG TCMS Network shall be scalable up to 32 switches on ETB level without gateways (64 in total in 2xWLTB). | Y | | |
| *New Requirement* | WLTB-AETBN-001 | The wireless safe train inauguration shall consist 2 physical WLTBs | Y | X | Redundancy will be used in Phases 3-4 of the demonstrator. |
| *Requirement* | DBD_ND_030 | Each ECN shall be connected to two ETBs via two ETBNs. | Y | X | Redundancy will be used in Phases 3-4 of the demonstrator. |
| *Modified Requirement* | DBD_ND_031 | One AETBN shall connect ECN to one physical WLTB ~~line~~. *Note: ~~Two ETB lines A and B.~~ Each AETBN is connected to one of the two physical WLTBs and to ECN.* | Y | X | Redundancy will be used in Phases 3-4 of the demonstrator. |
| *Modified Requirement* | DBD_ND_032 | ETBN shall transfer non-TSN data between ECNs on one physical WLTB ~~line.~~<br>*Note: Link aggregation is not used.* | Y | X | |
| *New Requirement* | WLTB-AETBN-002 | The 2 physical WLTBs shall inaugurate separately and each of the physical WLTB shall compute its own TTDB | Y | X | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *New Requirement* | WLTB-AETBN-003 | After the inauguration is done, by comparing the two TTDBs from each physical WLTB, a common TTDB will be computed and provided to CCU<br><br>Note. Theoretically, the TTDBs would be the same if no failure occurs | Y | X | |
| *New Requirement* | WLTB-AETBN-004 | One physical WLTB shall be able to run different train application on different logical WLTBs, and each of the logical WLTB shall use different WLTB ID<br><br>e.g.<br>Physical WLTB 0 with 2 logical WLTBs with TCMS (ID 0) and OMTS (ID 1)<br>Physical WLTB 1 also with 2 logical WLTBs with TCMS (ID 0) and OMTS (ID 1) | Y | X | |
| *New Requirement* | WLTB-AETBN-005 | The wireless safe train inauguration shall only take place on TCMS logical WLTB (WLTB ID 0 of physical WLTB 0 and 1), other train subsystems run on different logical WLTB shall follow the computed result from TCMS TTDB | Y | X | For a consist, CN attached to different WLTB IDs shall contain exactly same amount |
| *Requirement* | DBD_ND_033 | ETBN shall use neighbour discovery results to dynamically select ETB line used for non-TSN data transfer between any two neighbour consists.<br>*Note: non-TSN data are transferred in dedicated VLAN on ETB. Tunnelling of this VLAN through ECN might be used to switch non-TSN traffic from one ETB line to the other within a consist.* | N | | VLAN reconfiguration addresses the line failure recovery within the same physical ETB. Requirement WLTB-AETBN-006 is added. |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *New Requirement* | WLTB-AETBN-006 | If any AETBN failures on the WLTB is detected by the master AETBN, it shall become backup AETBN and shift the master role to the backup AETBN | Y | X | The failure could be detected by TOPO frame timeout, and it is covered in IEC 61375-2-5. Therefore, it is only needed to shift the master role from the master to backup AETBN |
| *Requirement* | DBD_ND_051 | Train Inauguration shall be safety-related function of safety integrity level (SIL) 2. | Y | | |
| *Requirement* | DBD_ND_052 | Train inauguration function shall perform ETB topology discovery and Operational Train Inauguration. | Y | X | |
| *Requirement* | DBD_ND_053 | ETBN shall use TTDP protocol specified in IEC 61375-2-5 for ETB topology discovery with the improvements for NG-TCN topology Wireless Inauguration topology. | Y | X | |

Table 16: Network Level Inauguration Requirements

## 3.3 Device Level Inauguration Requirements

### *3.3.1 ETB neighbour discovery (for D topology)*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_054 | ETBN shall use TTDP protocol HELLO frames for neighbour discovery on ETB. | N | | HELLO frames removed in wireless inauguration |
| *Requirement* | DBD_ND_055 | When both ETBNs in a consist are functional the ETBN on line A shall send HELLO frames on both ETB lines in DIR 1 and the ETBN on line B shall send HELLO frames on both ETB lines in DIR 2.<br>*Note: The aim is to emulate serial connection of ETBNs on ETB as specified in IEC 61375-2-5 even though ETBNs are in fact connected in parallel - one to each ETB line.* | N | | HELLO frames removed in wireless inauguration |
| *Requirement* | DBD_ND_056 | ETBN shall use a dedicated VLAN to forward HELLO frames to its partner-ETBN in the same consist via ECN. | N | | HELLO frames removed in wireless inauguration |
| *Requirement* | DBD_ND_057 | When one ETBN in a consist fails the other ETBN shall transmit own HELLO frames to the connected ETB line in both directions. | N | | HELLO frames removed in wireless inauguration |
| *Requirement* | DBD_ND_058 | When both ETBNs in a consist are functional the ETBN on line A shall process HELLO frames received from both ETB lines in DIR 1 and the ETBN on line B shall process HELLO frames received from both ETB lines in DIR 2.<br>*Note: Symmetrical to HELLO transmission - the aim is to emulate serial connection of ETBNs on ETB as specified in IEC 61375-2-5.* | N | | HELLO frames removed in wireless inauguration |
| *Requirement* | DBD_ND_059 | When one ETBN in a consist fails the other ETBN shall process HELLO frames received from both directions on the connected ETB line. | N | | HELLO frames removed in wireless inauguration |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *New Requirement* | WLTB-AETBN-007 | The AETBN shall be able to retrieve up-to-date neighbour consist information listed below from the RFID transponders installed at the frontend and backend of the consist<br>• the consist identifier (consist id) of the local consist<br>• the direction information ( end in direction 1 or end in direction 2) of the local consist<br>• the identifier of the WLTB and WLTBN<br>o WLTB ID (this ID must be unique)<br>o WLTBN ID (these IDs must be unique), the adapted ETBN MAC address will be taken. | Y | X | RFID transponders will be emulated, via changes in database inside AETBN.<br><br>RAMS analysis related to RFID transponders will be done in upcoming Shift2Rail projects. |
| *New Requirement* | WLTB-AETBN-008 | The AETBN shall communicate with the RFID transponders via SIL 2 safety communication | Y | X | RFID transponders will be emulated, via changes in database inside AETBN.<br><br>RAMS analysis related to RFID transponders will be done in upcoming Shift2Rail projects. |
| *New Requirement* | WLTB-AETBN-009 | The AETBN shall refer to the result of TOPOLOGY frame for discovery of neighbour aliveness instead of using TTDP HELLO frames | Y | X | |
| *New Requirement* | WLTB-AETBN-010 | The AETBN shall refer to the transmission period of HELLO frame for transmitting the TOPOLOGY frame<br>• SlowPeriod 100 ms<br>• SlowTimeout 1,3 × SlowPeriod = 130 ms<br>• FastPeriod 15 ms<br>• FastTimeout 3 × FastPeriod = 45 ms<br>Detection time = SlowTimeout + FastTimeout = 175 ms | Y | X | |

Table 17: ETB neighbour discovery (for D topology)

### 3.3.2 ETB topology discovery

| Type | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_060 | ETBN shall transmit TTDP protocol TOPOLOGY frames in both directions on ETB as non-TSN data.<br>Note: TOPOLOGY frames belong to non-TSN data category and therefore are transmitted on one ETB line only in each direction. | Y | X | |
| *Modified Requirement* | DBD_ND_061 | AETBN shall receive TOPOLOGY frames from all other AETBNs on the same physical WLTB.<br>~~*Note: Since serial connection between ETBNs is emulated each ETBN receives TOPOLOGY frames from ETBNs connected to either ETB line.*~~ | Y | X | |
| *New Requirement* | WLTB-AETBN-011 | The AETBN shall build the connectivity vector (partial view) by using the information retrieved from RFID transponder | Y | X | RFID transponders will be emulated, via changes in database inside AETBN.<br>RAMS analysis related to RFID transponders will be done in upcoming Shift2Rail projects. |
| *Requirement* | DBD_ND_062 | ETBN shall use received TOPOLOGY frames to calculate Train Network Directory as specified in IEC 61375-2-5. | Y | X | |
| *Requirement* | DBD_ND_063 | ETBN shall compute the Train Network Directory with tolerable functional failure rate (TFFR) of less than 10^-6/h to achieve safety integrity level SIL2. | Y | | |
| *New Requirement* | WLTB-AETBN-012 | The AETBN shall adopt the new TOPOLOGY frame structure defined in [2] Annex A. | Y | X | |
| *New Requirement* | WLTB-AETBN-013 | The AETBN shall transmit TOPOLOGY frames via SIL 2 safety communication | Y | X | For the demonstrator, the adapted TOPOLOGY frame will be protected with SC-32 (data integrity). |
| *New Requirement* | WLTB-AETBN-014 | If selected wireless forwarding / routing protocol works in L3, the AETBN shall encapsulate the TOPOLOGY frame in an IP package and send it using a multicast IP address | Y | X | |

Table 18: ETB topology discovery

### 3.3.3 Inauguration requirements

| Type | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_064 | The ETBN shall provide TTDB information to TI validator via TTDB manager interface defined in IEC 61375-2-3, and shall transfer data via safe data transmission protocol (e.g. SDTv4). | Y | | RAMS analysis related to TI validator will be done in upcoming Shift2Rail projects. |
| *Requirement* | DBD_ND_065 | The ETBN shall support dynamic VLAN reconfiguration to handle ETB line and ETBN failover for non-TSN traffic. | N | | |
| *Requirement* | DBD_ND_066 | The ETBN shall support up to 32 logical ECNs in each consist | Y | | |
| *Requirement* | DBD_ND_067 | The ETBN shall support local subnet addressing defined in IEC 61375-2-5 chapter 6.4.2 on ECN side. | Y | X | |
| *Modified Requirement* | DBD_ND_068 | The ETBN shall support WLTB ID 0 and WLTB ID 1. | Y | X | - |
| *Requirement* | DBD_ND_069 | The ETBN shall support the beacon proxy function. | N | | Not needed, since the direction of the consist does not imply that the beacon will arrive from one WLTB or another one. |

Table 19: Inauguration requirements

## 3.4 Network Device - Clock Synchronisation Requirements

### *3.4.1 Clock Sync Time Dissemination ETB*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_101 | The network shall forward the timing information coming from world clock or system time generator to the end devices. | *Y (To be analysed in T2.6)* | | LTE modules have their own synchronization mechanisms. However, it needs to be checked if they are able to share it using IEEE 802.1AS or IEEE 1588. |
| *Requirement* | DBD_ND_102 | Upon unrecoverable loss of synchronization, the ETBN shall stop synchronous time-aware operations. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_103 | The ETBN shall be a time-aware device as defined in 802.1AS-rev. | *N (To be analysed in T2.6)* | | |
| *Modified Requirement* | DBD_ND_104 | The ETBN shall include a precise clock which can be configured as GMC | *Y (To be analysed in T2.6)* | | LTE modules get GMC from GPS or some other source (e.g. base station, or master UE in D2D) |
| *Requirement* | DBD_ND_105 | Master clock drift shall be <2ppm per second. | *Y (To be analysed in T2.6)* | | The phase drift could also be an issue |
| *Modified Requirement* | DBD_ND_106 | ETBN shall synchronize by using redundant time information from multiple ~~gPTP~~ clock domains. | *Y (To be analysed in T2.6)* | | |
| *Modified Requirement* | DBD_ND_107 | Device synchronization configuration shall enable synchronization to ~~gPTP~~ clock domains from only one train synchronization domain. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_108 | ETBN clocks in the first and the last consist on both communication lines shall act as GMCs. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_109 | ETB grandmasters clock (GMC) shall provide time information to the configured synchronization domain. | *N (To be analysed in T2.6)* | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_111 | ETBN switch shall police all synchronization packets. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_114 | ETB GMC shall send time information on a dedicated stream (traffic class) according to its priority and topology position. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_115 | The priority of each GMC shall have values 0<priority<8. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_116 | Each GMC shall have a unique priority within its synchronization domain. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_117 | A grandmaster clock (GMC) shall disseminate time information by using IEEE 802.1AS-rev messages. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_118 | GMCs shall send clock information using Sync packets at defined time instants, within the Sync packet transmission period.<br>Note: This applies after synchronous startup for all GMCs. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_119 | GMC shall monitor Sync packet order and arrival time. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_120 | Configuration of GMCs and network shall ensure that all Sync packets are received at expected order, within a defined period. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_121 | GMCs shall ignore ANNOUNCE messages and BMCA algorithms. | *N (To be analysed in T2.6)* | | |

Table 20: Clock Sync Time Dissemination ETB

### *3.4.2 Synchronization Architecture – Grandmaster Clock, Synchronous Startup on Power-Up*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_122 | On synchronous startup and if external time reference is available, the highest-priority GMC shall abruptly adjust his clock to the external reference time. | *To be analysed in T2.6* | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_123 | On power-up, if an external time reference is not available, the highest priority GMC shall start sending Sync messages with its own RTC as a timebase. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_124 | The acquired time from an external time reference will be disseminated as a correction factor to the existing system time. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_125 | During the TCMS grandmasterclock (GMC) synchronization startup, the higher priority GMCs shall supply its own timebase (local clock) to the lower priority GMCs. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_126 | During the TCMS grandmasterclock (GMC) synchronization startup, a GMC shall align its time to higher priority GMCs' times within the Sync message period. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_127 | During the TCMS grandmasterclock (GMC) synchronization startup, in case of abrupt time changes coming from higher priority GMCs lower-priority GMCs shall detect such time changes. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_128 | During the TCMS grandmasterclock (GMC) synchronization startup, in case of abrupt time changes coming from higher priority GMCs lower-priority GMCs shall tolerate time changes if their consecutive number is lower than 2. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_129 | During the TCMS grandmasterclock (GMC) synchronization startup, in case of abrupt time changes coming from higher priority GMCs lower-priority GMCs shall tolerate such abrupt time changes if the number of GMCs on ETB is higher than 2. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_130 | During the TCMS masterclock (MC) synchronization startup, the lower priority MCs shall ignore higher priority GMCs which over a configured period exhibit implausible behaviour. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_131 | TCMS grandmaster clock (GMC) synchronization startup shall initialize after a completed topology discovery as part of the inauguration procedure. | *To be analysed in T2.6* | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_132 | ETBN shall begin synchronization after successful TCMS grandmaster clock (GMC) synchronization startup. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_133 | ETB GMC from the last ETBN in topology shall synchronize to the ETB GMC in the 1st ETBN on both communication lines after 1st train power-up and completion of ETB inauguration. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_134 | After completed synchronous startup, GMC shall obtain information from other GMCs on its own clock quality. Note: independent external monitoring. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_135 | An ETBN shall synchronously start-up within a predefined maximum period of time. | *To be analysed in T2.6* | | |

Table 21: Synchronization Architecture – Grandmaster Clock, Synchronous Startup on Power-Up

### *3.4.3 Synchronization Architecture – Master Clock Resynchronization*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_136 | GMC shall align their clocks in precision of <=5µs | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_137 | If the time difference is higher than 5µs for more than a defined period of time, then GMC shall go into inactive state until next power-up. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_138 | If the majority of other GMCs is not aligned with GMC for more than 10 seconds, then GMC shall go into inactive state until next power-up. | *To be analysed in T2.6* | | |

Table 22: Synchronization Architecture – Master Clock Resynchronization

### 3.4.4 Synchronization Slaves and Network Traffic Control

| Type | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_139 | ETBN shall use time information from gPTP clock domains for fault detection, preselecting correct clocks and tolerating faulty clock sources. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_140 | Network devices shall monitor the origin (sender) of gPTP packets using MAC DEST and VLID / streamIDs and priority information. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_141 | Synchronization slave devices shall monitor the order of gPTP packets using sequence numbers. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_142 | Ordinary clock (OC) slaves shall diagnose and identify correct time by adapting the calculation approach, depending on the number of gPTP clock domains active and available:<br>* For 1 active – take it as is with PDV;<br>* For 2 active – average over two values, if within 5microseconds (ECN) or 10 microseconds (ETB), otherwise non-conclusive;<br>* For 3 active - voting 2oo3 voting for 3 clocks, takes 2 clocks which are within 5 microseconds (ECN) or 10 microseconds (ETB), average over 2 correct gPTP instants, otherwise non-conclusive;<br>* For 4 active - discarding the highest and lowest value and averaging over two remaining values assuming their difference is within 5microseconds (ECN) or 10 microseconds (ETB), otherwise non-conclusive. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_143 | The ETBN shall switch to the Inactive Mode, if unable to synchronize to the global GMC time values within the configured grace period (e.g. 1 sec). | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_144 | The ETBN shall switch from Inactive to the Inauguration Mode upon external request. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_145 | ETBN shall tolerate link interruptions or failures of up to 1 second, before they are allowed to transfer into inactive mode. | *To be analysed in T2.6* | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_146 | The ETBN shall continue synchronous (GCL list) operation using the local clock time within a configured grace period. (e.g. at least 1sec), if there is no reliable information to identify correct/valid time sources. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_147 | ETB configuration shall define a standardized number of streams for transmission to the 1st and last consist, and from/to ECN, depending on its topology position. | *To be analysed in T2.6* | | |

Table 23: Synchronization Slaves and Network Traffic Control

## 3.5 Network Device - ETB Services Requirements

### *3.5.1 TTDB, ECSP*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Modified Requirement* | DBD_ND_201 | The ETBN shall be able to exchange consist information with all ETBNs on the same physical WLTB | Y | X | Both AETBN of the consist should do it. |
| *Modified Requirement* | DBD_ND_202 | ~~If the ETBN is the active ECSP within the consist, it shall be entitled to send and receive the CSTINFO telegrams for the consist~~<br><br>The ETBN shall be responsible to send and receive the CSTINFO telegrams class 1 on the same physical WLTB | Y | X | Both AETBN of the consist should do it. |
| *Requirement* | DBD_ND_203 | The ETBN may support closed train<br>- CSTINFO telegram class 2 and class 3 | Y | | |
| *Requirement* | DBD_ND_204 | The ETBN shall provide a safe storage for TTDB, which is a repository for all the information related to the actual train composition and the actual ETB state<br>- Consist information<br>- Train network directory<br>- Train directory<br>- Operational train directory | Y | X | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_205 | The TTDB shall be maintained by a TTDB Manager function, and it shall always keep the TTDB up-to-date | Y | X | |
| *Requirement* | DBD_ND_206 | The ETBN may support TTDB for multiple ETBs | Y | | |
| *Requirement* | DBD_ND_207 | The ETBN shall support computation of the train directory | Y | X | |
| *Requirement* | DBD_ND_208 | If train inaugurations are not inhibited, the ETBN shall (re-)compute the train directory each time there is a change of the etbTopoCnt. | Y | X | |
| *Requirement* | DBD_ND_209 | The ETBN shall support DNS server for resolving TCN-URI host part to IP addresses with the aid of the TCN-DNS as defined in IEC 61375-2-3 Clause 5.4.2 | Y | X | |
| *Requirement* | DBD_ND_210 | The ETBN shall map TCN-URI to IP multicast group addresses in accordance to the IP addressing scheme defined in IEC 61375-2-3 Clause 5.4.5.2 | Y | X | |
| *Requirement* | DBD_ND_211 | The ETBN shall map TCN-URI to IP addresses in accordance to the IP addressing scheme defined in IEC 61375-2-5 Clause 6.4 | Y | X | |
| *Requirement* | DBD_ND_212 | The ETBN shall provide DNS server service for TCN URI scheme defined in IEC 61375-2-3 Clause 5.4.4 | Y | X | |
| *Requirement* | DBD_ND_213 | The ETBN shall implement the standard DNS protocols as specified in RFC 1034 and RFC 1035 | Y | X | |
| *Requirement* | DBD_ND_214 | The ETBN shall support TRDP DNS server interface according to IEC 61375-2-3 annex E | Y | X | |
| *Requirement* | DBD_ND_215 | The ETBN shall only provide ETB control service on the operational network (ETB 0) | Y | | |
| *Modified Requirement* | DBD_ND_407 | The ETBN shall support ECSP election mechanism to select the master AETBN, the other ETBN becomes backup AETBN ~~ensure only one ECSP is active at one time within a consist~~ | Y | X | |
| *Requirement* | DBD_ND_217 | A failure of the ECSC shall be detected latest after a time of $T_{ECSC\_fail}$ = 5,0 s | Y | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_218 | If a failure is detected, the ECSP shall react as defined for the individual ETB control service functions. | Y | | |
| *Modified Requirement* | DBD_ND_219 | The ETBN shall be responsible to send and receive safe ETBCTRL telegram on the same physical WLTB cyclically using SDTv4 as defined in IEC 61375-2-3 Clause 6.4 | Y | | |
| *Modified Requirement* | DBD_ND_220 | In case of multiple logical WLTBs ~~ETBs,~~ ETBCTRL telegrams shall only be exchanged on the operational network (ETB0 of each physical WLTB). | Y | | ETBCTRL will be sent by the AETBN of each physical WLTB. |
| *Modified Requirement* | DBD_ND_221 | The ETBN shall collect ETBCTRL telegrams received from all ECSPs on the same physical WLTB, including the own ECSP as well as the remote ECSPs | Y | X | |
| *Requirement* | DBD_ND_222 | The ETBN shall support computation of the operational train directory | Y | X | |
| *Requirement* | DBD_ND_223 | The ETBN shall compute a new operational train directory each time there is a change of<br>- Train Directory<br>- Collection of ETBCTRL telegrams received from all ECSPs | Y | X | |
| *Requirement* | DBD_ND_224 | The ETBN shall support leading function to elect one of the vehicles within the train to become the leading vehicle | Y | X | |
| *Requirement* | DBD_ND_225 | The ETBN shall be able to detect leading conflict | Y | X | |
| *Requirement* | DBD_ND_226 | The ETBN shall be able to indicate leading conflict to the ECSC latest 1.0s after detection | Y | | |
| *Requirement* | DBD_ND_227 | The ETBN shall follow the rules to determine the operational directions defined in IEC 61375-2-3 Clause 4.2.4.3 | Y | X | |
| *Requirement* | DBD_ND_228 | The ETBN may support sleep mode function as defined in IEC 61375-2-3 | Y | | |
| *Requirement* | DBD_ND_229 | The ETBN shall enter sleep mode if there is a request from all consists, and leave if there are demands from at least one consist | Y | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_230 | The ETBN shall provide ECSP interface according to IEC 61375-2-3 annex E | Y | X | |
| *Requirement* | DBD_ND_231 | The ETBN shall provide TTDB manager interface according to IEC 61375-2-3 annex E | Y | X | The AETBN will have to implement both client and server sides, acting as an ED (see WLTB-AETBN-015). |
| *New Requirement* | WLTB-AETBN-015 | The ETBN shall preform as ED in TTDB manager interface to retrieve the TTDB from paired ETBN | Y | X | |
| *Requirement* | DBD_ND_232 | The ETBN TTDB manager shall support a new specific telegram using non-safe data communication for providing own cstUUID value within the consist | Y | | |
| *Requirement* | DBD_ND_233 | The ETBN may provide ETBN control interface according IEC 61375-2-3 annex E | Y | X | |
| *Requirement* | DBD_ND_234 | The ETBN shall send TRDP process data telegrams with IEEE 802.1p traffic priority class 3 | Y | X | |
| *Requirement* | DBD_ND_235 | The ETBN shall send TRDP message data telegrams with IEEE 802.1p traffic priority class 2 | Y | X | |
| *Requirement* | DBD_ND_236 | The ETBN shall support the safe ECSP status telegram transmission using SDTv4 | Y | | |
| *Requirement* | DBD_ND_237 | The ETBN shall support the safe TTDB information telegram transmission using SDTv4 | Y | | |
| *Requirement* | DBD_ND_238 | The ETBN shall support the safe ETBCTRL telegram transmission using SDTv4 | Y | | |
| *Requirement* | DBD_ND_239 | The ETBN shall be able to receive safe ECSP control telegram using SDTv4 | Y | | |

Table 24: TTDB, ECSP

## 3.6 Network Device - Flow Control Requirements

### *3.6.1 Frame Identification, Queues, Priorization, Scheduled Traffic*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_271 | The Network Device shall transfer datasets with a defined period, transmission time for each multi-cast. | N | | |
| *Requirement* | DBD_ND_272 | The Network Device configuration shall contain all data sets and multi-cast sent from each consist to all other consists. | N | | |

Table 25: Frame Identification, Queues, Priorization, Scheduled Traffic

### *3.6.2 Ingress Policing*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Modified Requirement* | DBD_ND_273 | Network Device shall support per flow policing according to 802.1Qci or equivalent | Y | | Will not be supported by Rel. 14 |
| *Modified Requirement* | DBD_ND_274 | Network Device shall support per flow policing of asynchronous dataflows according to 802.1Qci or equivalent on queues with priority 0, 1 and 2. | Y | | Will not be supported by Rel. 14 |
| *Modified Requirement* | DBD_ND_275 | Network Device shall support per flow policing of synchronous dataflows according to 802.1Qci or equivalent on priority higher than 1. | Y | | Will not be supported by Rel. 14 |
| *Modified Requirement* | DBD_ND_276 | Network Device shall support Stream identification function according to 802.1CB or equivalent | *To be analysed in T2.6* | | Will not be supported by Rel. 14. The Ethernet header with CB fields should be reconstructed when doing NAT |
| *Requirement* | DBD_ND_277 | The Network Device shall police all critical multi-cast messages using the same configuration data for traffic from left (toward leading car) and right (opposite from leading car) side. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_278 | The Network Device shall police and forward multi-cast message which are specified only for its topology position. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_279 | The Network Device shall contain a stream filter table in which the filtering and policing actions per stream filter are defined. | *To be analysed in T2.6* | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_280 | The Network Device shall contain a stream gates table in which the opening and closing states and events per stream gate are defined. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_281 | The stream gates table shall contain a stream gate control list for ingress traffic. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_282 | The Network Device shall contain flow meters instance table in which flow parameters are defined. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_283 | The Network Device shall use the time information from valid and correct gPTP clock domains to align the cyclic operation of IEEE TSN Gate Control Lists (GCL). | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_284 | The ETBN shall police and prevent synchronization SYNC traffic from any ECN, not being the consist 1 or last consist. | *To be analysed in T2.6* | | |

Table 26: Ingress Policing

### *3.6.3 Egress Policing*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_285 | The ND shall support adding, recognizing, interpreting, and removing VLAN tags as defined in IEEE 802.1Q. | Y | X | |
| *Requirement* | DBD_ND_286 | The ND shall support strict priority-based transmission selection algorithm (IEEE 802.1Q) | Y | X | |
| *Requirement* | DBD_ND_287 | The ND may support credit-based shaper algorithm (IEEE 802.1Q) | Y | | |
| *Requirement* | DBD_ND_288 | Network Device shall support time-driven packet switching and forwarding (802.1Qbv) with capability to send packets in a defined time period. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_289 | Network Device shall support at least 8 egress queues. | Y | X | |
| *Requirement* | DBD_ND_290 | Network Device shall have a gate control list (GCL) for every egress port that defines gate operations. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_291 | Each GCL shall allow at least 64 entries. | *To be analysed in T2.6* | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_292 | Network Device shall initiate the execution of the gate control list at startup. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_293 | Network Device shall ensure that the gating cycle time defined for the port is maintained | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_294 | Network Device shall execute the gate operations in the gate control list, in sequence | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_295 | Network Device shall establish the appropriate time delay between each operation | *To be analysed in T2.6* | | |

Table 27: Egress Policing

## 3.7 Network Device - Gateway Requirements

### *3.7.1 ETBN/ECN-Gateway*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_351 | TSNGW shall collect and store all system-relevant time-sensitive (or critical) traffic from ECNs. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_352 | TSNGW shall collect and periodically disseminate incoming train-relevant data from other TSNGWs to its local ECN, and vice versa. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_353 | TSNGW shall periodically/deterministically disseminate system-relevant data in line with schedule. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_354 | TSNGW shall send only to configured stream identifiers, with configured timing and periodicity depending on its position in the topology. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_355 | TSNGW shall collect all the train-relevant data in datasets multicast from other ETB switches for forwarding to its connected ECN nodes. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_356 | GCL list period for gate control shall be configurable at least 2.5ms | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_357 | TSNGW shall inspect and store received ECN packets which contain system-relevant data and match configured packet header identifiers (e.g. MAC SRC/DEST, VLID, …). | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_358 | TSNGW shall inspect and forward received ECN packets to ETBN, only if they match the configured packet headers. | *To be analysed in T2.6* | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_359 | TSNGW shall inspect and forward received ETB packets to ECN network, only if they match the configured packet headers. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_360 | TSNGW shall disassemble ECN packet data with application CRC according to configuration. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_361 | TSNGW shall assemble datasets, consisting of at least one ECN packet data. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_362 | With each piece of data assembled, the data freshness timer (system time stamp) will be stored. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_363 | Only provably correct data (CRC, bitwise comparison, redundant data etc.) shall be used for the assembly of datasets.<br><br>Note: for invalid data will not be stored and data freshness will not be updated, therefore the last generation of data will be used. | *To be analysed in T2.6* | | |

Table 28: ETBN/ECN-Gateway

### *3.7.2 TSNGW Configuration*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_365 | TSNGW shall store the complete constructed dataset into configured ETB_SHMEM_POSITION(n).<br>Note: n = constant sampling memory position defined by configuration data. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_366 | For each ECN packet sent to ECN, and assembled from ETB_SHMEM data, TSNGW configuration shall define for each data piece, the source of the dataset (ETB_SHMEM _POSITION(n)),its exact position in the dataset, and data length. | *To be analysed in T2.6* | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_367 | Configuration Parameters: For each dataset parameter or variable, the TSNGW configuration shall define: the source of the ECN data (packet header identifiers, MAC SRC/DEST) and its length (LEN) and position (FR_POS) in the frame. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_368 | TSNGW shall send datasets from “ETB SHMEM” at configured time instants by using a predefined data stream packet identifier (SRC MAC, DEST MAC, VLAN ID/priority, IP Address, UPD port) | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_369 | A dataset from “ETB SHMEM”, the TSN packet shall multicast to all other ETBNs, when an interval/period timer indicates the time is ready for transmitting at least one packet associated with this periods, as defined by configuration. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_370 | TSNGW shall provide configuration (5) for mapping of ECN packet data to ETB datasets | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_371 | TSNGW shall provide configuration (6) for periodic sending of the consist’s own ETB datasets. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_372 | TSNGW shall provide configuration (2,3) for mapping of ETB datasets data to ECN packets. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_373 | TSNGW shall provide configuration (4) for periodic sending of consist’s own ETB datasets. | *To be analysed in T2.6* | | |

Table 29: TSNGW Configuration

### 3.7.3 Status and Health of TSNGW

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_374 | TSNGW shall periodically collect and store its own ETB switch health status including port error statistics from MIB list:<br>• For left and right ETB port<br>• for ETB to ECN port<br>• for ETB to TSNGW port | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_375 | TSNGW shall collect and store its own ETB switch current state (synchronous, asynchronous, …), as they occur (event-driven). | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_376 | TSNGW shall periodically collect and store gPTP synchronization information and history from at least one second (100x). | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_377 | TSNGW health status and/or synchronization history, or their constituents shall be disseminated via ETB to other consists periodically, if configured. | *To be analysed in T2.6* | | |
| *Requirement* | DBD_ND_378 | TSNGW health status and/or synchronization history, or their constituents shall be disseminated to ECN on request. | *To be analysed in T2.6* | | |

Table 30: Status and Health of TSNGW

## 3.8 Network Device - Redundancy Requirements

### *3.8.1 802.1CB related requirements*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_401 | NG TCN shall transfer TSN data between ECNs on both ETB lines in redundant data streams. | *Y (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_402 | The Network Device shall support the forwarding of frames duplicated according to 802.1CB FRER | *Y (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_403 | The Network Device shall be able to remove R-TAG from incoming frames | *Y (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_404 | The Network Device shall re-insert R-TAG into outgoing frames if they carried R-TAG on ingress (unrecognized/unconfigured streams). | *Y (To be analysed in T2.6)* | | |

Table 31: 802.1CB related requirements

### *3.8.2 VRRP related requirements*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_405 | The ETBNs within a consist shall use VRRPv3 over the ECN to select a master router for routing of non-TSN unicast traffic between ECN and ETB. | Y | X | |
| *Requirement* | DBD_ND_406 | The ETBN which is currently selected master by the VRRP shall also be responsible for routing non-TSN multicast traffic between ECN and ETB. | Y | X | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_407 | The ETBN which is currently selected master by the VRRP shall also act as "active" ECSP, while the VRRP backup will be passive ECSP. | N | | Requirement not needed. New requirements are added to replace DBD_ND_407<br><br>In general, ECSP is responsible for providing TTDB information and ETB control service. In wireless inauguration, both master and backup AETBN shall provide ETB control service, but only the master AETBN shall provide TTDB information to CCU. |
| *New Requirement* | WLTB-AETBN-016 | After the inauguration is done, the master AETBN shall be responsible for retrieving the TTDB from the backup AETBN including the information below via TTDB manager interface defined in IEC 61375-2-3<br>- Consist information<br>- Train network directory | Y | X | |
| *New Requirement* | WLTB-AETBN-017 | The master AETBN shall compute a common and complete TTDB by comparing the TTDBs from different WLTBs, and obtaining the corresponding information of the missing consist | Y | X | |
| *New Requirement* | WLTB-AETBN-018 | The master AETBN shall be responsible of providing the common TTDB information to CCU if the common TTDB is computed successfully without contradiction | Y | X | |
| *New Requirement* | WLTB-AETBN-019 | The master AETBN shall notify the result of the computation to backup AETBN, and also share the complete TTDB if it is computed successfully without contradiction | Y | X | |
| *New Requirement* | WLTB-AETBN-020 | The master and backup AETBN shall exchange the TTDB information and computation result via a dedicated VLAN | Y | X | |
| *New Requirement* | WLTB-AETBN-021 | Both active and backup AETBN shall provide ETB control service | Y | X | The ECSC in the CCU shall send separate ECSP control telegrams to both master and backup AETBN. |
| *Requirement* | DBD_ND_408 | The ETBN shall support device redundancy with switch-over time of ≤ 0.8 s. | Y | | |

Table 32: VRRP related requirements

## 3.9 Network Device - Network Management Requirements

### *3.9.1 DHCP, DNS, other generic network services*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_451 | The ETBN ports shall support the reception and transmission of Ethernet frames in accordance to IEEE 802.3 | Y | X | |
| *Requirement* | DBD_ND_452 | ETBN shall act as a router between ECN and ETB for unicast and multicast IP packets including network address translation | Y | X | |
| *Requirement* | DBD_ND_453 | ETBN shall support IP as defined in RFC791 | Y | X | |
| *Requirement* | DBD_ND_454 | ETBN shall support ARP as defined in RFC826 | Y | X | |
| *Requirement* | DBD_ND_455 | ETBN shall support UDP as defined in RFC768 | Y | X | |
| *Requirement* | DBD_ND_456 | ETBN shall support TCP as defined in RFC793 | Y | X | |
| *Requirement* | DBD_ND_457 | ETBN shall support ICMP as defined in RFC792 | Y | X | |
| *Requirement* | DBD_ND_458 | ETBN shall support IGMP Message Format as defined in RFC3376 Clause 4 | Y | | |
| *Requirement* | DBD_ND_459 | ETBN shall support IGMP Router Filter-Mode as defined in RFC3376 Clause 6.2.1 | Y | | |
| *Requirement* | DBD_ND_460 | ETBN shall support IGMP Querier Election as defined in RFC3376 Clause 6.6.2 | Y | | |
| *Requirement* | DBD_ND_461 | ETBN shall support IGMP Interoperation With Older Versions of IGMP as defined in RFC3376 Clause 7 | Y | | |
| *Requirement* | DBD_ND_462 | ETBN shall support IGMP Query Interval setting as defined in RFC3376 Clause 8.14.2 | Y | | |
| *Requirement* | DBD_ND_464 | ETBN shall support DHCP server to provide IPv4 address allocation as defined in RFC2131 Clause 3. | Y | | |
| *Requirement* | DBD_ND_465 | ETBN may support DHCP server to provide Router Option as defined in RFC 2132 Clause 3.5 | Y | | |
| *Requirement* | DBD_ND_466 | ETBN shall support DHCP server to provide Domain Name Server option as defined in RFC2132 Clause 3.8 | Y | | |
| *Requirement* | DBD_ND_467 | ETBN shall support DHCP server to provide IP Address Lease Time option as defined in RFC2132 Clause 9.2 | Y | | |
| *Requirement* | DBD_ND_468 | ETBN shall support DHCP server to provide TFTP Server Name option as defined in RFC2132 Clause 9.4 | Y | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_469 | ETBN shall support DHCP server to provide Boot file Name option as defined in RFC2132 Clause 9.5 | Y | | |
| *Requirement* | DBD_ND_470 | ETBN may support DHCP server to provide Client-identifier option as defined in RFC 2132 Clause 9.14 | Y | | |
| *Requirement* | DBD_ND_471 | ETBN may support DHCP server to provide Relay-agent information - Server operation as defined in RFC 3046 | Y | | |
| *Requirement* | DBD_ND_473 | ETBN shall support IEC61375-2-5 MIB to meet requirements which is defined in ETBN inauguration sheet | Y | X | |
| *Requirement* | DBD_ND_474 | ETBN shall support IEC61375-2-3 MIB to meet requirements which is defined in ETBN Service sheet | Y | X | |

Table 33: DHCP, DNS, other generic network services

## 3.10 Network Device - Communication Integration Layer Requirements

### *3.10.1 TRDP-related requirements*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_501 | The ETBN shall support TRDP process data protocol for the exchange of TCN process data | Y | X | |
| *Requirement* | DBD_ND_502 | The ETBN shall support TRDP message data protocol for the exchange of TCN message data | Y | X | |
| *Requirement* | DBD_ND_503 | The ETBN shall send TRDP process data telegram with UDP | Y | X | |
| *Requirement* | DBD_ND_504 | The TRDP process data packet size shall be restricted to the size of one Ethernet frame | Y | X | |
| *Requirement* | DBD_ND_505 | The ETBN shall send TRDP message data with UDP or with TCP | Y | X | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_506 | The ETBN shall use the well-known ports for receiving any process data telegrams and for receiving UDP message data notification, request and confirm telegrams | Y | X | |
| *Requirement* | DBD_ND_507 | The ETBN shall use a private source port different from the well-known port for sending any process data telegrams and for sending UDP message data notification, request and confirm telegrams | Y | X | |
| *Requirement* | DBD_ND_508 | The ETBN shall use the same port related to request for receiving UDP message data reply telegrams | Y | X | |
| *Requirement* | DBD_ND_509 | The ETBN shall use any source port different from the one the request was received from for sending UDP message data reply telegrams. | Y | X | |
| *Requirement* | DBD_ND_510 | The TRDP TCP connections shall be established between a source port different from the well-known port and the well-known port as destination. | Y | | |
| *Requirement* | DBD_ND_511 | The ETBN may use different well-known port numbers for project specific purposes. | Y | | |
| *Requirement* | DBD_ND_512 | The ETBN shall compute TRDP FCS CRC according to IEC 61375-2-3 annex A.3 | Y | X | |
| *Requirement* | DBD_ND_513 | The ETBN shall support push communication pattern to transmit PD-PDUs cyclically | Y | X | |
| *Requirement* | DBD_ND_514 | The ETBN shall support pull communication pattern to transmit PD-PDUs on request | Y | | |
| *Requirement* | DBD_ND_515 | The ETBN shall use an IP unicast address for addressing a known process data subscriber/publisher. | Y | X | |
| *Requirement* | DBD_ND_516 | The ETBN shall use an IP multicast address for addressing groups of known process data subscribers/publishers (e.g. redundancy groups). | Y | X | |
| *Requirement* | DBD_ND_517 | The ETBN shall use an IP multicast address for addressing unknown process data subscribers/publishers. | Y | X | |
| *Requirement* | DBD_ND_518 | The ETBN shall send process data telegram according to the PD-PDU structure defined in IEC 61375-2-3 annex A.6.5 | Y | X | |
| *Requirement* | DBD_ND_519 | The ETBN shall support TRDP PD redundancy groups | Y | X | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_520 | The ETBN shall follow the PD protocol state machine defined in IEC 61375-2-3 annex A.6.8 | Y | X | |
| *Requirement* | DBD_ND_521 | If the ETBN support pushed PD-PDU, it shall apply a traffic shaping mechanism for equal distribution of the PD-PDU's over the time | Y | | |
| *Requirement* | DBD_ND_522 | The TRDP message data packet size shall be limited to 64 Kbytes | Y | X | |
| *Requirement* | DBD_ND_523 | The ETBN shall support MD push and pull communication pattern | Y | X | |
| *Requirement* | DBD_ND_524 | The ETBN shall support the following message data transfer options<br>a) request without reply ('notification')<br>b) request with reply but without confirmation<br>c) request with reply and confirmation | Y | X | |
| *Requirement* | DBD_ND_525 | As a message data caller, the ETBN shall use an IP unicast address or an IP multicast address for addressing known replier(s) | Y | X | |
| *Requirement* | DBD_ND_526 | As a message data caller, the ETBN shall use an IP multicast address for addressing unknown repliers. | Y | X | |
| *Requirement* | DBD_ND_527 | As a message data caller, the ETBN may use an IP multicast address for addressing a known replier redundancy group. | Y | X | |
| *Requirement* | DBD_ND_528 | As a message data replier, the ETBN shall respond to the caller's unicast address. | Y | X | |
| *Requirement* | DBD_ND_529 | The ETBN shall send message data telegram according to the MD-PDU structure defined in IEC 61375-2-3 annex A.7.5 | Y | X | |
| *Requirement* | DBD_ND_530 | The ETBN shall support the filtering rules according to IEC 61375-2-3 annex A.7.6.3 | Y | | |
| *Requirement* | DBD_ND_531 | The ETBN shall follow the MD protocol state machine defined in IEC 61375-2-3 annex A.7.8 | Y | X | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_532 | As a message data caller, the ETBN shall close an existing TCP connection (active end) if one of the following conditions is met:<br>• A signal that the TCP connection will be closed has been received.<br>• TRDP shut down or re-initialization.<br>• A timeout occurred because the TCP connection has not been used for a defined time. | Y | | |
| *Requirement* | DBD_ND_533 | As a message data replier, the ETBN shall use the TCP connection opened by the caller. | Y | | |
| *Requirement* | DBD_ND_534 | As a message data replier, the ETBN shall close an existing TCP connection (passive end) if one of the following conditions is met:<br>• A signal that the TCP connection will be closed has been received.<br>• TRDP shut down or re-initialization.<br>• Another TCP connection was opened from the same caller device and the old connection is not used anymore for a defined time. | Y | | |
| *Requirement* | DBD_ND_535 | The ETBN may support MD echo function | Y | | |
| *Requirement* | DBD_ND_536 | The ETBN shall provide topography counter check specified in IEC 61375-2-3 annex A.6.7 and A 7.7 | Y | X | |
| *Requirement* | DBD_ND_537 | If the topography counter check fails before sending a telegram, the ETBN shall not send the telegram | Y | X | |
| *Requirement* | DBD_ND_538 | If the topography counter check fails after receiving a telegram, the ETBN shall not accept the telegram | Y | X | |
| *Requirement* | DBD_ND_539 | If the TRDP configuration is not supported, the ETBN shall support the default TRDP configuration value as in IEC 61375-2-3 annex C | Y | X | |

Table 34: TRDP-related requirements

### *3.10.2 SDTv4-related requirements*

The following table contains the requirements related to SDTv4, which has been selected by CONNECTA-2 over SDTv2.

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_571 | The ETBN shall provide independent safety and standard (regular) communication | Y | X | |
| *Requirement* | DBD_ND_572 | The ETBN shall follow the algorithm for SC-32 algorithm defined in IEC 61375-2-3 annex B.7 for SID and Safety Code computation | Y | X | |
| *Requirement* | DBD_ND_573 | The ETBN shall implement SC-32 and the coding of SID for TRDP protocol only. | Y | X | |
| *Requirement* | DBD_ND_574 | The ETBN shall identify a source identifier (SID) for each safety related data source (SDSRC) | Y | X | |
| *Requirement* | DBD_ND_575 | As a SDSRC, the ETBN shall encapsulate safety critical data in a vital data packet (VDP), and the VDPs are transmitted within the user data part of a TRDP process data telegram | Y | X | |
| *Requirement* | DBD_ND_576 | As a SDSRC, the ETBN shall produce the VDP periodically | Y | X | |
| *Requirement* | DBD_ND_577 | As a SDSRC, the ETBN shall increment the safe sequence counter (SSC) for each produced VDP | Y | X | |
| *Requirement* | DBD_ND_578 | As a SDSRC, the ETBN shall produce VDPs only when a valid SDI is computed | Y | X | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_579 | As a SDSRC, the ETBN may support redundancy defined in IEC 61375-2-3 annex B.12.3.2 only for increased availability | Y | | |
| *Requirement* | DBD_ND_580 | As a SDSINK, the ETBN shall compute the SIDs of expected VDPs from SDSRC according to the information from TTDB | Y | X | |
| *Requirement* | DBD_ND_581 | As a SDSINK, the ETBN shall provide the following validation when receiving VDPs from SDSRC<br>- Integrity check (B13.5)<br>- Sink time supervision (B13.6)<br>- Guard time check (B13.7)<br>- Latency monitoring (B13.8)<br>- Channel monitoring (B13.9) | Y | X | |
| *Requirement* | DBD_ND_582 | If the received VDP pass all validation, the ETBN shall consider the communication channel is safe | Y | X | |
| *Requirement* | DBD_ND_583 | If a train composition change occurs, the ETBN shall not affect the SDTv4 channel within a consist | Y | X | |
| *Requirement* | DBD_ND_584 | The ETBN should provide the statistic counters listed in IEC 61375-2-3 Table B.5 | Y | | |

Table 35: SDTv4-related requirements

## 3.11 Network Device - Health Monitoring Requirements

### *3.11.1 TRDP-signalling-related requirements*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_601 | The ETBN shall send out TTDB status telegram periodically | Y | X | |
| *Requirement* | DBD_ND_602 | The ETBN shall provide TTDB information on request | Y | X | |
| *Requirement* | DBD_ND_603 | The ETBN may support TRDP echo function | Y | | |
| *Requirement* | DBD_ND_604 | The ETBN shall send out ECSP status telegram to ECSC periodically | Y | X | |
| *Requirement* | DBD_ND_605 | The ETBN shall send out ETBN status telegram periodically with multicast destination address | Y | | |

Table 36: TRDP-signalling-related requirements

### *3.11.2 SNMP protocol requirements*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_621 | The network device shall support SNMP. | Y | | |
| *Requirement* | DBD_ND_622 | The network device shall be capable of exchanging SNMP messages securely using SNMPv3. | Y | | |

Table 37: SNMP protocol requirements

### 3.11.3 SNMP MIB requirements with respect to health monitoring

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_623 | It shall be possible to read out Ethernet port operational status via SNMP | Y | X | |
| *Requirement* | DBD_ND_624 | It shall be possible to get an SNMP Notification (Trap/Notify/Report) when an Ethernet port changes state. | Y | X | |
| *Requirement* | DBD_ND_625 | ND shall provide packet error counters via SNMP to facilitate better Diagnostic Coverage (DC) in the case of an increasing bit error probability. | Y | X | |
| *Requirement* | DBD_ND_626 | It shall be possible to use SNMP to read out ingress and egress packet statistics to facilitate monitoring of packet loss rate. | Y | X | |
| *Requirement* | DBD_ND_627 | It shall be possible to use SNMP to read out ingress and egress packet statistics to facilitate monitoring of link load. | Y | | |
| *Requirement* | DBD_ND_628 | It shall be possible to use SNMP to read out ETBN operational state for router redundancy role (master/backup/other) | Y | | |
| *Requirement* | DBD_ND_629 | It shall be possible to get an SNMP Notification (Trap/Notify/Report) when a redundant router changes operational role. | Y | | |
| *Requirement* | DBD_ND_630 | It shall be possible use SNMP to read out Ring Status of the ECN Ring Redundancy protocol (intact/broken) | Y | | |
| *Requirement* | DBD_ND_631 | It shall be possible to get an SNMP Notification (Trap/Notify/Report) when the ECN ring changes state (intact => broken or vice versa) | Y | | |

Table 38: SNMP MIB requirements with respect to health monitoring

# 3.12 Network Device - Configuration Requirements

## *3.12.1 Config setting requirements*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_651 | IP Address: Static IP addresses of the switches shall be set. | Y | X | |
| *Requirement* | DBD_ND_652 | DHCP Server: When DHCP is available for dynamic IP addressing and the ECSP is located within the ETBN, the DHCP server shall be configured. | Y | | |
| *Requirement* | DBD_ND_653 | Port settings: Port assignment and ingress and egress policing configuration shall be set. | Y | X | |
| *Requirement* | DBD_ND_654 | VLAN configuration: For traffic distinction within the networks as well as for network management, VLAN configuration shall be set in the network devices ports. More detailed information about this configuration can be found in the chapter 3.2.6 of this deliverable. | Y | X | |
| *Requirement* | DBD_ND_655 | TSN Gateway settings: Scheduled data streams must be predefined according to application specific requirements. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_656 | TSNGW: When the gateway is located within the ETBN, the configuration for ETB/ECN data mapping and the configuration of the ETB/ECN scheduled data shall be set. | *N (To be analysed in T2.6)* | | |
| *Requirement* | DBD_ND_657 | Static consist information: When ECSP is located within the ETBN, the static consist information as detailed in IEC61375-2-3 shall be configured. | Y | X | |
| *Requirement* | DBD_ND_659 | ETB Inauguration (TTDP) settings: Settings required for the ETBN to conduct ETB inauguration according to IEC 61375-2-5 | Y | X | |
| *Requirement* | DBD_ND_660 | Settings required for the ETBN to act as redundant router for non-TSN traffic on ECN and ETB. | Y | X | |
| *Requirement* | DBD_ND_661 | Settings required for the ETBN to act as firewall. | Y | | |

Table 39: Config setting requirements

## 3.13 Network Device - Physical and Environmental Requirements

### *3.13.1 Form-factor related requirements, connectors, dimensions, etc*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_701 | The ETBN shall provide at least 3 Ethernet ports following IEEE 802.3 with<br>· 2 ports GbE for ETB connection<br>· 1 port GbE for ECN connection | Y | X | Same requirement as DBD_ND_01 |
| *Requirement* | DBD_ND_702 | The Network Device shall use Ethernet M12 X-coded 8-pin female connector for Gigabit Ethernet port according to IEC 61076-2-109 | Y | X | A-coded 4-pin for demonstrator |
| *Requirement* | DBD_ND_703 | The Network Device shall be at least an IP30 class device | Y | | |
| *Requirement* | DBD_ND_704 | The Network Device should support wall or rack mounting for installation | Y | X | |
| *Requirement* | DBD_ND_705 | The Network Device shall provide a console for maintenance / debugging | Y | | |
| *Requirement* | DBD_ND_706 | The Network Device may provide a reset function to reset the user configurations | Y | | |
| *Requirement* | DBD_ND_707 | The Network Device may provide an out-of-band Ethernet port for maintenance | Y | | |
| *Requirement* | DBD_ND_708 | The Network Device may provide system indicators, at least ok and sum of error indication | Y | | |
| *Requirement* | DBD_ND_709 | The Network Device may provide port status indicators (link, traffic, blocked) | Y | | |

Table 40: Form-factor related requirements, connectors, dimensions, etc

### 3.13.2 Power related requirements

| Type | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_710 | The Network Device shall support input power voltage 24V, and should support the range 24V-110V. | Y | X | |
| *Requirement* | DBD_ND_711 | The Network Device may use M12 K-coded 5-pin male or M12 A-coded 4-pin male connector as the power connector. | Y | | |
| *Requirement* | DBD_ND_712 | The power consumption of the Network Device should not exceed 30W (non-PoE) | Y | | |

Table 41: Power related requirements

### 3.13.3 EMC related requirements

| Type | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_721 | The Network Device shall comply with EN 50155:2017 class OT4, -40 °C to +70 °C | Y | | |
| *Requirement* | DBD_ND_722 | The Network Device shall comply with EN 50121-3-2:2015 | Y | | |
| *Requirement* | DBD_ND_723 | The Network Device shall comply with EN 50124-1:2017 | Y | | |
| *Requirement* | DBD_ND_724 | The Network Device shall comply with EN 50125-1:2014 | Y | | |
| *Requirement* | DBD_ND_725 | The Network Device shall comply with EN 50125-3:2014 if signalling functions are integrated on TCMS network | Y | | |
| *Requirement* | DBD_ND_726 | The Network Device shall comply with EN 45545-1:2013 | Y | | |
| *Requirement* | DBD_ND_727 | The Network Device shall comply with EN 45545-2:2013 | Y | | |
| *Requirement* | DBD_ND_728 | The Network Device shall comply with EN 45545-5:2013 | Y | | |
| *Requirement* | DBD_ND_729 | The Network Device shall comply with EN 50126-1:2017 | Y | | |
| *Requirement* | DBD_ND_730 | The Network Device shall comply with EN 50657:2017 | Y | | |
| *Requirement* | DBD_ND_731 | The Network Device shall comply with EN 50128:2011 if signalling functions are integrated on TCMS network | Y | | |
| *Requirement* | DBD_ND_732 | The Network Device shall comply with EN 50129:2018 | Y | | |

Table 42: EMC related requirements

## 3.14 Network Device - Security Requirements

### *3.14.1 Port Network Access Control*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_803 | ETBN may be capable of acting as IEEE 802.1x Authentication Server (RADIUS) | Y | | |
| *Requirement* | DBD_ND_805 | If ETBN supports IEEE 802.1X Authentication Server, it shall support EAP method(s) supporting derivation of master key derivation for MACsec. | Y | | |

Table 43: Port Network Access Control

### *3.14.2 Firewall functionality*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_806 | ETBN shall provide a network-based firewall service | Y | | |
| *Requirement* | DBD_ND_807 | ETBN shall be able to filter IP telegrams at least based on IP source address, IP destination address, Source port (UDP/TCP), Destination port (UDP/TCP) and TRDP ComId | Y | | |

Table 44: Firewall functionality

### *3.14.3 Protocols for secure device management*

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_808 | Network device shall support HTTPS for secure file transfer | Y | | |
| *Requirement* | DBD_ND_809 | Network device shall support SSH for secure login | Y | | |
| *Requirement* | DBD_ND_810 | Network device shall support syslog for logging if security related events | Y | | |

Table 45: Protocols for secure device management

### 3.14.4 Logging-related security requirements

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_811 | The network device shall support detection and reporting of security events | Y | | |
| *Requirement* | DBD_ND_812 | If a user logs in, the concerned device shall create a log message including the user name. | Y | | |
| *Requirement* | DBD_ND_813 | If a user login fails in maximum tries, the concerned device shall create a log message including the user name and the connection details of the client. | Y | | |
| *Requirement* | DBD_ND_814 | A network device shall generate an audit log message whenever any of the following events occur:<br>- Creation of a new user account<br>- Deletion of a user account<br>- Modification of the privilege level, or group membership, of a user account | Y | | |
| *Requirement* | DBD_ND_815 | A network device shall generate an audit log message whenever any of the following events occurs:<br>- A user spawns a shell, terminal or other application or command using different user credentials than his own (e.g. uses sudo)<br>- A user changes his effective user credentials, group membership, privilege level, or similar credentials (e.g. uses su). | Y | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| | | | | | |
| *Requirement* | DBD_ND_816 | A network device shall generate an audit log message whenever any of the following events occurs:<br>- A user changes his password or any other persistent authentication token<br>- A user password or other authentication token is changed for any other reason, or<br>- Grant, modify, or revoke access rights, including adding a new user or group, changing user privilege levels, changing file permissions, changing database object permissions | Y | | |
| *Requirement* | DBD_ND_817 | When the firewall is taken up during system operation, the concerned device shall generate firewall log messages. | Y | | |
| *Requirement* | DBD_ND_818 | When the firewall is taken down during system operation, the concerned device shall generate firewall log messages. | Y | | |
| *Requirement* | DBD_ND_819 | When the firewall is reconfigured, reinitialized, or reloaded at runtime, the concerned reconfiguration device shall generate firewall log messages. | Y | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_820 | When unexpected traffic is received on the external interface, the concerned device shall generate a firewall log message.<br>Note: The firewalls are configured via a white list. All traffic not included in the white list is unexpected.<br>This applies only to the internal firewall between network zones. | Y | | |
| *Requirement* | DBD_ND_821 | A device shall create a log message whenever a security-related system service is started. | Y | | |
| *Requirement* | DBD_ND_822 | A device shall create a log message whenever a security-related system service gets shut down. | Y | | |
| *Requirement* | DBD_ND_823 | A device shall create a log message whenever the system as a whole starts up or enters an operational state.<br>Message shall include run level and firmware version. | Y | | |
| *Requirement* | DBD_ND_824 | A device shall create a log message whenever the system gets rebooted, including a reboot reason/trigger. | Y | | |
| *Requirement* | DBD_ND_825 | A device shall create a log message whenever the system gets shut down. | Y | | |
| *Requirement* | DBD_ND_826 | A device shall create a log message whenever an attempt is made to update the system software and specify whether the attempt was successful. The log message should also include the previous and current version numbers of the software. | Y | | |

| *Type* | Req ID | Description | Prod. | Dem. | Notes |
|---|---|---|---|---|---|
| *Requirement* | DBD_ND_827 | A device that support a dedicated maintenance mode, used for testing, debugging, fault-finding or software updates or similar tasks, shall create a log message when entering this mode. | Y | | |
| *Requirement* | DBD_ND_828 | A device that support a dedicated maintenance mode, used for testing, debugging, fault-finding or software updates or similar tasks, shall create a log message when exiting this mode. | Y | | |
| *Requirement* | DBD_ND_831 | Network device shall generate a log message whenever a connection loss to an externally accessible device is detected on the physical or link layer. This only applies to the originator device to which the externally accessible device was directly connected. | Y | | |
| *Requirement* | DBD_ND_832 | Network device shall generate a log message whenever a connection to an externally accessible device is established on the physical or link layer. This only applies to the originator device to which the externally accessible device is directly connected. | Y | | |
| *Requirement* | DBD_ND_833 | Devices may generate a log message when they drop log messages to prevent a flooding of the network. The text of the message should contain the number of messages dropped if known. | Y | | |

Table 46: Logging-related security requirements

# Chapter 4 Summary and Conclusion

This deliverable has detailed the requirements, which must fulfil LTE equipment and ETBNs in order to be integrated in a wireless train backbone for a wireless train inauguration. These requirements will be used as a baseline for subsequent tasks in WP2 of Safe4RAIL-2 which are related to the WLTB. For example, requirements for LTE equipment detailed in Chapter 2 will be used in Task 2.2 (“Design and implementation of LTE equipment and impact analysis on ETBNs”), and requirements for AETBNs detailed in Chapter 3 will be used in Task 2.3 “Interoperability tests for Wireless Train Backbone”. In addition, requirements from D2.1 will also be used for analysing demanding WLTB scenarios in Task 2.4 (“Analysis of challenging wireless scenarios”), and also for evaluating the integration of all on-board wireless systems in Task 2.5 (“Integration of on-board and signalling wireless systems”). On the other hand, Task 2.6 (“DbD concept evolution towards wireless Train Backbone”) will also be strongly related to the requirements detailed in this deliverable, as those AETBN requirements linked to Drive-by-Data will be re-analysed in this task.

Finally, the requirements presented in this deliverable will also be used as an input for tasks dealing more advanced technologies and applications, such as Task 2.7 (“Applicability of 5G Technology on Wireless TCMS”) and Task 2.8 (“Future wireless technologies for virtual coupling”).

# Chapter 5 List of Abbreviations

| | |
|---|---|
| AETBN | Adapted ETBN |
| AODV | Ad hoc On-Demand Vector |
| ARP | Address Resolution Protocol |
| BER | Bit Error Rate |
| BMCA | Best Master Clock Algorithm |
| CCU | Central Control Unit |
| CN | Consist Network |
| CRC | Cyclic Redundancy Check |
| CTA | CONNECTA |
| D2D | Device to Device |
| DbD | Drive-by-Data |
| DC | Diagnostic Coverage |
| DHCP | Dynamic Host Configuration Protocol |
| DNS | Domain Name System |
| EAP | Extensible Authentication Protocol |
| ECN | Ethernet Consist Node |
| ECSP | ETBN Control Service Provider |
| ED | End Device |
| EMC | Electro-Magnetic Compatibility |
| ETB | Ethernet Train Backbone |
| ETBN | Ethernet Train Backbone Node |
| ETSI | European Telecommunications Standards Institute |
| FCS | Frame Check Sequence |
| FRER | Frame Replication and Elimination for Reliability |
| GbE | Gigabit Ethernet |

| | |
|---|---|
| GCL | Gate Control List |
| GMC | Grand Master Clock |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| gPTP | Generalized Precision Time Protocol |
| GSMR | Global System for Railway Mobile communications |
| HTTP | Hypertext Transfer Protocol |
| ICMP | Internet Control Message Protocol |
| ID | Identifier |
| IEC | International Electrotechnical Commission |
| IEEE | Institute of Electrical and Electronics Engineers |
| IETF | Internet Engineering Task Force |
| IGMP | Internet Group Management Protocol |
| IP | Internet Protocol |
| ISM | Industrial, Scientific and Medical |
| ITS | Intelligent Transport System |
| LLPD | Link Layer Discovery Protocol |
| LTE | Long Term Evolution |
| MAC | Media Access Control |
| MANET | Mobile Ad-hoc Networks |
| MD | Message Data |
| MIB | Management Information Base |
| NAT | Network Address Translation |
| ND | Network Device |
| NG- | Next Generation (TCN/TCMS) |
| OC | Ordinary Clock |
| OS | Operating System |
| OSI | Open System Interconnection |

| | |
|---|---|
| PD | Process Data |
| PDU | Process Data Unit |
| PDV | Packet Delay Variation |
| PoE | Power over Ethernet |
| ProSe | Proximity Services |
| PTP | Precision Time Protocol |
| QoS | Quality of Service |
| RAMS | Reliability, Availability, Maintainability, Safety |
| RB | Resource Block |
| RD | Radio Device |
| RFC | Remote Function Call |
| RFID | Radio-Frequency IDentification |
| RTC | Real-Time Clock |
| SDT | Safe Data Transmission |
| SID | Source IDentifier |
| SIL | Safety Integrity Level |
| SIM | Subscriber Identity Module |
| SNMP | Simple Network Management Protocol |
| SNR | Signal to Noise Ratio |
| SPS | Semi-Persistent Scheduling |
| SSC | Safe Sequence Counter |
| SSH | Secure SHell |
| TCMS | Train Control and Monitoring System |
| TCN | Train Communication Network |
| TCP | Transmission Control Protocol |
| TFFR | Tolerable Functional Failure Rate |
| TFTP | Trivial File Transfer Protocol |
| TRDP | Train Real Time Data Protocol |

| | |
|---|---|
| TS | Technical specification |
| TSN | Time-Sensitive Networking |
| TTDB | Train Topology DataBase |
| TTDP | Train Topology Discovery Protocol |
| TX | Transmitter |
| UDP | User Data Protocol |
| URI | Uniform Resource Identifier |
| V2X | Vehicle-to-Everything |
| VDP | Vital Data Packet |
| VLAN | Virtual Local Area Network |
| VLID | Virtual Link Identifier |
| VRRP | Virtual Router Redundancy Protocol |
| WLTB | Wireless Train Backbone |
| WLTBN | Wireless Train Backbone Node |

Table 47: List of Abbreviations

# Chapter 6 Bibliography

[1] Safe4RAIL-2, “Deliverable D1.1 - Drive-by-Data Requirements Specification”, April 2019.

[2] CONNECTA-2, “CTA2-T1.1-T-CAF-029-01 - Specification of the Wireless Train Inauguration”