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D3.2

Physical reference system architecture FDFT

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1. Executive Summary

This document constitutes “Deliverable 3.2 Physical reference system architecture FDFT” of ER JU Flagship Area 5 project FP5-TRANS4M-R. This document reports results from Task 3.3: Specification of physical and data reference system architecture.

The objective of this document is to provide the physical reference system architecture and requirements based on deliverable D3.1 Functional system architecture FDFT in conjunction with deliverable D2.2 User requirements of WP2 of ER JU FP5 TRANS4M-R. The physical system architecture will define the basis for the development of the innovations for WP5-WP12. It describes the **target of full automation of the freight sector**, as well as a subset based on the agreed technical enablers in FP5-TRANS4M-R.

The physical requirements are followed by the **Physical reference system architecture** including an overview as well as the physical blocks required in FDFT traction units and FDFT wagons. To allow un-restrained innovations to be used, when designing the technical enablers in FP5-TRANS4M-R, the document focusses at the physical requirements in an open way, as much as possible.

Keywords: Physical System Requirements; Physical Reference System Architecture; Full Automation; Technical Enabler

2. Abbreviations & Acronyms

Abbreviation / Acronym	Description
3GPP	3rd Generation Partnership Project The 3GPP is responsible for the development and maintenance of various mobile communication standards
ABT	Automated Brake Test
ASO	Automatic Shunting Operation
ATO	Automatic Train Operation
ATP	Automatic Train Protection
BMS	Battery Management System
CCU	Consist Control Unit
CPSS	Consist power supply system
DAC	Digital Automatic Coupler
DAC CU	Digital Automatic Coupler Control Unit
Demo II	Due to concentration of project resources on train functions (as described in amendment #2) WP11 is focused now on the development of DAC uncoupling via push-button. Therefore, all features regarding the so-called Demo II trains are abandoned. For future purposes these features are considered in the system architecture as Demo II functions without further description.
ECN	Ethernet Consist Network
ED	End Device (here used in the context of the ECN)
EDDP	European DAC Delivery Programme
ERA	European Railway Agency
ER JU	Europe's Rail Joint Undertaking
F-ETB	Freight Ethernet Train Backbone
F-ETBN	Freight Ethernet Train Backbone Node
FDFT	Full digital freight train
FDFT Link	FDFT communication interface (IP based, e.g.: LTE Cat M1, WLAN)
FDFTO	Full Digital Freight Train Operation
F-TCN	Freight Train Communication Network
FPSE	Flagship Project System Engineers
GFM	Ground Fault Monitor
GCG	Ground Communication Gateway

HMI	Human Machine Interface for controlling and monitoring of a system (e.g.: lever, indicator, button, lamps, keyboard, display)
GNSS	Global Navigation Satellite System
I/F	Interface
LAN	Local Area Network
LCU	Loco Control Unit (i.e. CCU installed on a traction unit)
LTE	Long Term Evolution
LV	Low Voltage
MCG	Mobile Communication Gateway
MNO	Mobile Network Operator
NSAs	National Safety Authorities
OPEID	ID of activity as used in /WP2 D2.1/ Preliminary Operational Procedures
PDL	Power Distribution Line
SL	Security Level
tbd.	To be defined
TCMS	Train Control & Management System
TLV	Type Length Value packet
TPMS 2.0	Trusted Platform Module acc. to IEC 11889-1-4:2015
TRL	Technical Readiness Level
TSI	Technical Specifications for Interoperability
TUPSS	Traction Unit Power Supply System
WGC	Wayside Communication Gateway
WP	Working package
WPSS	Wagon Power Supply System

3. Background

The present document constitutes the Deliverable D3.2 “Physical reference system architecture FDFT” in the framework of the Flagship Project FP5- TRANS4M-R as described in the EU-RAIL MAWP and contributes as well to the Flagship Project FP5 TRANS4M-R.

The project aims to boost innovation for the European rail freight sector, concretely by developing, validating, and demonstrating TRANS4M-R technical enablers. The work to reach this level of TRL is complex and thus divided into several work packages highly dependent on each other. See WP structure in Figure 1 below

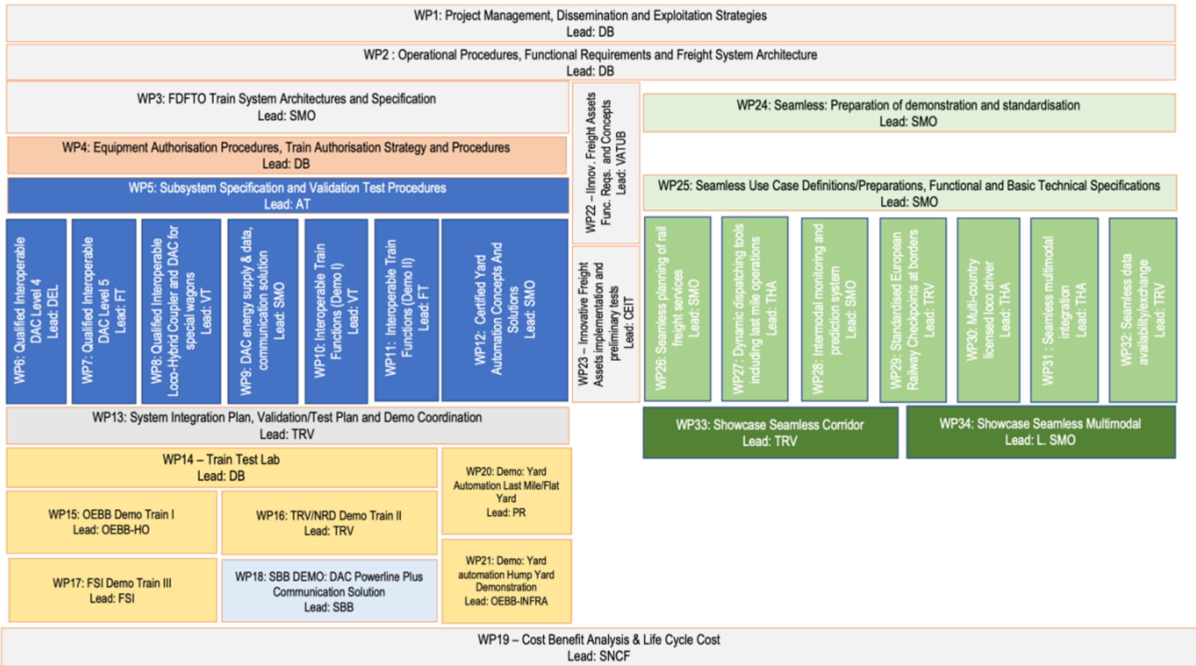

Figure 1: WP-structure in TRANS4M-R.

In WP3 the FDFTO train system architecture is defined based on various inputs either from operational requirements or from the specifications of the technical enablers for the FDFTO train.

4. Objective/Aim

The objective of this document is to provide a physical reference freight architecture FDFT concept as basis for the future work in FP5. It will be based on the functional reference system architecture concept, outlined in D3.1 and contains a description and specification for a physical reference system of rolling stock and the interfaces to the infrastructure.

4.1. Task Description

Task 3.3 started in month seven and the outputs of the task are included in this document as well as its sister document /WP3 D3.3/.

For the work a core team was established with experts for the relevant technical enablers. The team met after finishing /WP3 D3.1/ once a week to provide the relevant input to the document and to check if the input provided fits to the overall architectural concept.

Another group of experts was set up to ensure a continuous review process of the work done by the core team. This so-called review team, consisting of experts from other WPs, met once a month with the core team to discuss the preliminary results. The purpose of these joint meetings was to disseminate the working progress and to get early feedback from the experts of the other WPs. The draft versions of this deliverable have been available at any time in the FP5 ProjectPlace to all members of all WPs. After discussion and agreement in the WP3 core group, the feedback has been incorporated into the deliverable.

Additionally, a mid-term on-site workshop was held for the alignment of the work done so far and the closure of open points.

The following table gives the direct match of the task definition from the grant agreement with the output. According to the task description a description and specification of the reference system (wagon/locomotive/infrastructure) is required. The infrastructure part is not in the scope of this deliverable because it is covered in WP2. However, the interfaces between rolling stock and infrastructure are covered in this deliverable. The deliverable shall serve as basis for implementation design of every wagon. The scope of the deliverables is extended to traction units because they play a significant role in FDFTO.

	Task definition from proposal	Output of WP3

Task 3.3	Based on the outcomes of Task 3.2 a base system will be designed. A description and specification for a physical (wagon/locomotive/infrastructure) reference system as basis for implementation-design of every wagon and a specification for a digital/data (applications) reference system architecture.	Deliverable D3.2: Physical reference system architecture FDFT Deliverable D3.3: Data reference system architecture FDFT

5. FDFTO Physical reference system architecture

5.1. System of interest

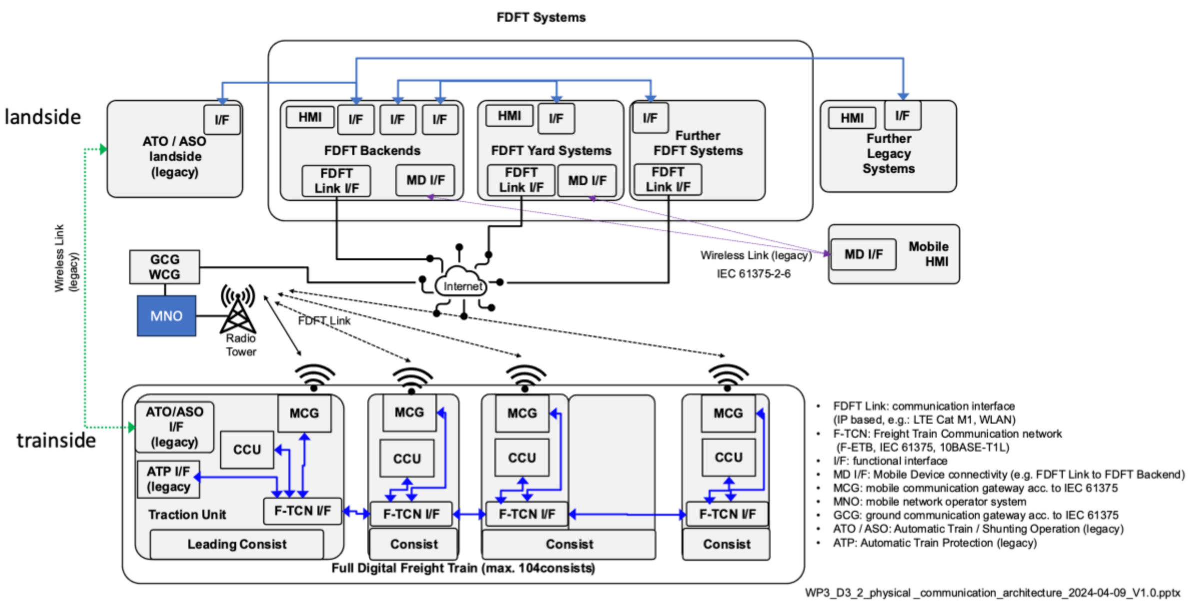

Figure 2: Overview of FDFTO physical communication architecture

The diagram above shows the FDFTO system as well as the split into landside and train side systems. The train side is covered by the FDFT system in /WP3 D3.2/ and /WP3 D3.3/, whereas the overall system architecture is covered in /WP2 D2.3/.

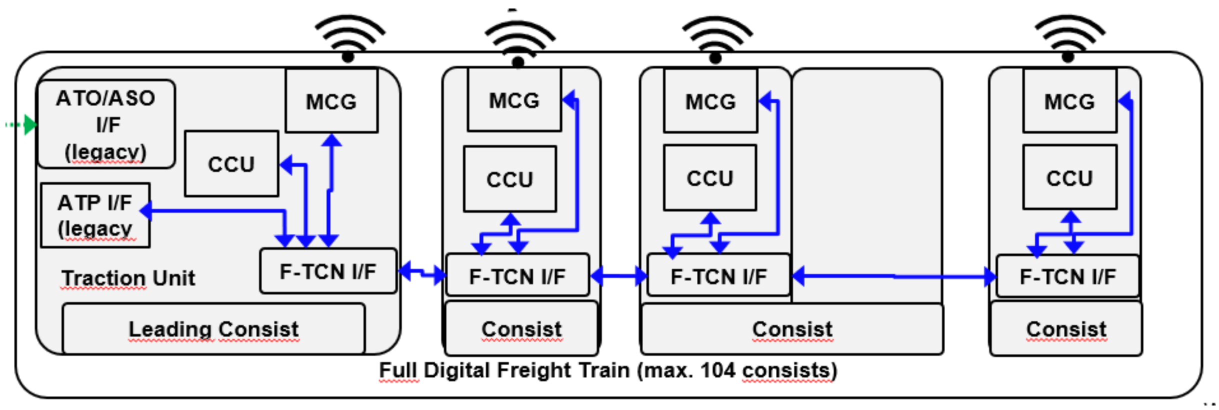

Figure 3: Overview of FDFTO train system

The diagram above shows the system of interest, described in this document. It comprises the FDFT consisting of up to 100 wagons (consists) and up to 4 traction units (consists).

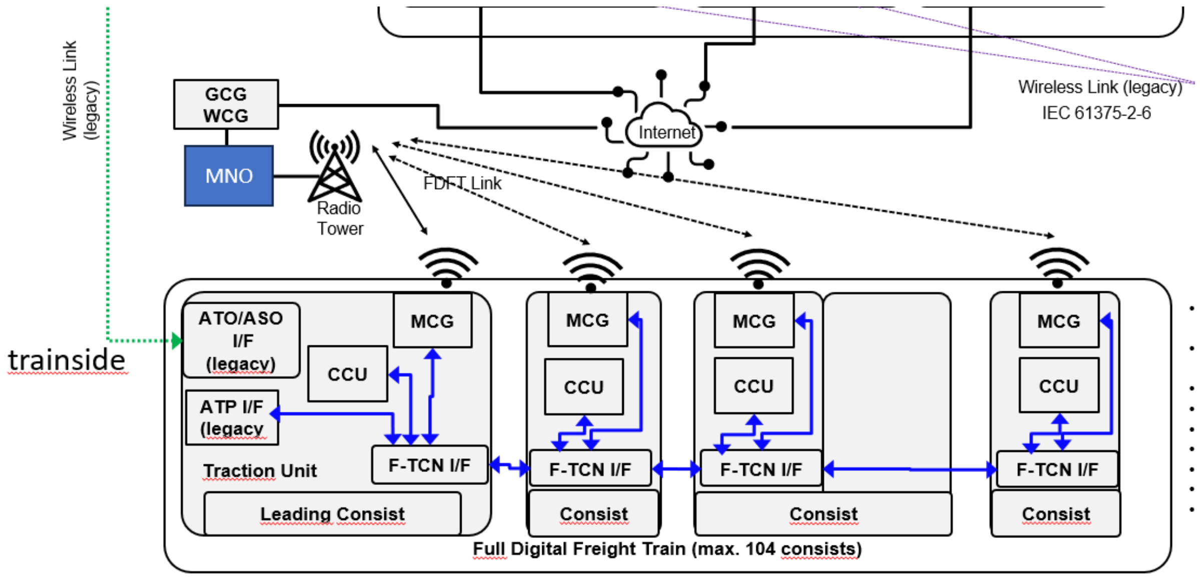

Figure 4: FDFT connectivity

The diagram above shows the connectivity of the FDFT with the landside. The connectivity is purely wireless (via FDFT link) and shall make use of either public mobile networks (e.g.: LTE) or Wi-Fi networks (foremost in small marshalling yards or customer sidings, where no public mobile network is available). The use of a Wi-Fi network shall be a fallback solution only.

The wireless connectivity shall enable the FDFT to communicate with the various FDFT backend systems, depending on required functionality.

The FDFT link shall be provided via the MCG (Mobile Communication Gateway) as defined in IEC 61375.

The communication with the landside shall be supported by all consists (traction units and wagons).

The communication inside the FDFT shall be performed via the F-ETB to allow a safe, secure, and reliable communication, and not via public wireless networks.

5.2. New functional requirements

When deriving the physical architecture from existing functional requirements in /WP3 D3.1/, new functional requirements might result. These new functional requirements are captured in this chapter.

5.2.1 Management interface of MCG

The management of the MCG to control the settings for the wireless FDFT-Link, requires an out-of-band interface between the CCU and the MCG. This interface is supplier specific.

5.3. Update of functional reference architecture

When deriving the physical architecture from existing functional reference system architecture /WP3 D3.1/, new functional blocks might become necessary. These new functional blocks are captured in this chapter.

No additional functional blocks are identified so far.

5.4. FDFTO wagon base system physical architecture

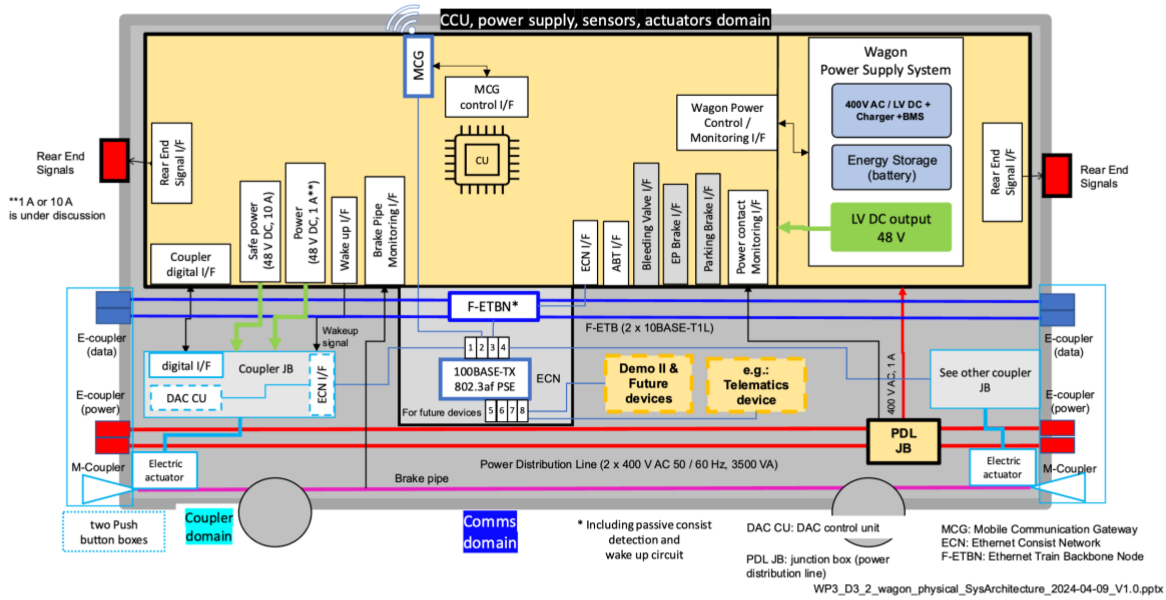

Figure 5: Overview on FDFTO wagon base system physical reference architecture

In the diagram above, the FDFTO wagon base system physical reference architecture is shown. This FDFTO wagon base system shall support all functional requirements as described in /WP3 D3.1/ by providing a consist internal communication system, a train-wide-communication system (the F-ETB), and a FDFT-Link (via MCG) for information exchange with the landside FDFT systems.

In addition to communication, the power supply and the consist related further requirements are defined (e.g.: interface to main brake pipe, braking actuators, ...).

The standardization of interfaces is restricted to those between the three domains (Coupler, Communication, CCU). All other interfaces can be implemented on a supplier specific approach, although the still following the general requirements as stipulated in chapter 5.7.

The requirements to the standardized interfaces are described hereinafter.

5.4.1 Coupler System

5.4.1.1 M-Coupler

This topic is covered in detail in /WP5 D5.2/ and described in the document covering the so-called coupler domain. There exists no direct interface with FDFT but indirectly via the coupler domain – CCU I/F.

The so-called hybrid coupler is not considered in this document: We consider only the DAC-part of this hybrid coupler, which shall behave identically to the DAC.

The hybrid coupler itself is described in /WP5 D5.2/.

5.4.1.2 E-Coupler

This topic is covered in detail in the deliverable /WP5 D5.2/. All aspects of mechanical layout, contacts selected, cover lid, ... are transparent to the physical reference system architecture.

For the physical reference system architecture, the E-coupler is providing the means of interconnecting the power distribution line and the F-ETBN between the consists.

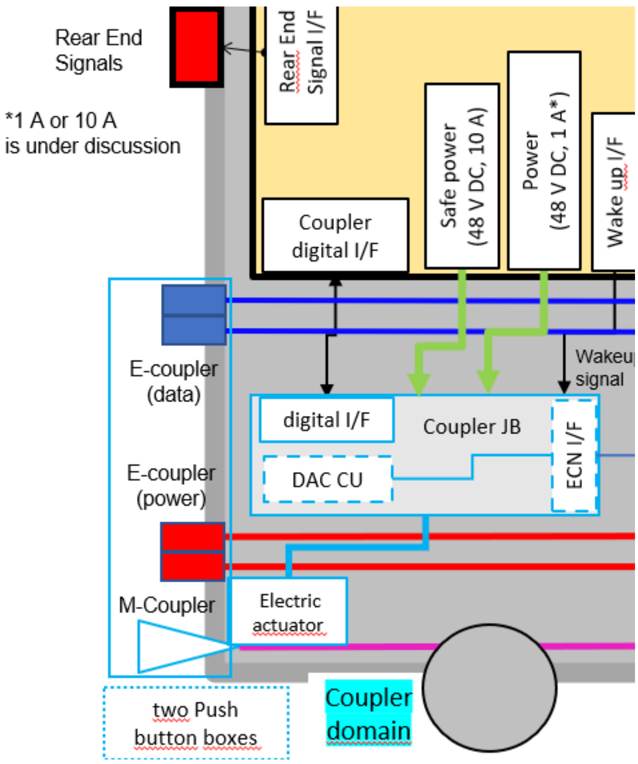

Figure 6: CCU - coupler interface

In the diagram above, the required interfaces between CCU domain and coupler domain are shown. As of now, two interface approaches (digital discrete vs. network based) shall be supported by the CCU to maintain the project time schedule for the so-called demo trains.

Both options will be developed and tested in parallel. Based on the outcome of these tests a final decision for one concept (either digital or network based) will be taken after field tests will have been performed.

5.4.2 Consist Control Unit

The consist control unit of the wagon hosts the train functions, which are defined in deliverable /WP5 D5.1/.

5.4.3 Wagon Power Supply System

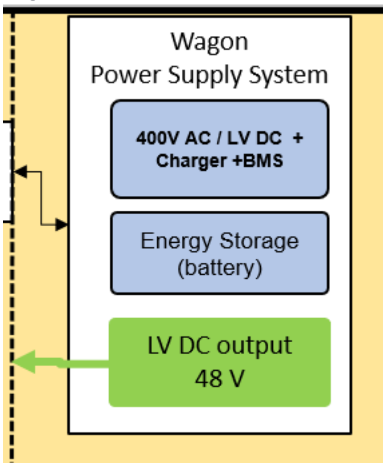

Figure 7: Wagon Power Supply System

The wagon power supply system is part of the CCU domain and thus is handled supplier specific.

5.4.3.1. Power Management Control Interface

This interface is supplier specific.

5.4.3.2. Power Management

The power management is supplier specific. The functional requirements from deliverable /WP3 D3.1/ shall be fulfilled.

5.4.3.3. Input 400 V AC

The power input from the 400 V AC power distribution line (PDL) into the wagon power supply system shall be restricted to a maximum of 50 W.

The wagon power supply system (WPS) shall ensure, that this standard power input isn't exceeded. The so-called inrush current might infringe the defined limit for a very short duration. The detailed requirements to the behaviour of the WPS are described in deliverable /WP5 D5.4/

The WPS shall work safely with power supplied over the power distribution line having the nominal voltage of 400 V AC.

The WPS shall support to work with a power frequency being at 50 Hz or 60 Hz nominal. Both frequencies shall be supported.

Rationale: If the power available at the PDL is supplied by a traction unit it might have a nominal frequency of 60 Hz, whereas if the power is provided from by a grid it has a nominal frequency of 50 Hz.

The WPS should be able to accept more power from the PDL upon remote request (for future use).

Rationale: This functionality gives the opportunity to recharge batteries faster, when more power for each wagon is available (e.g.: traction unit hauling less than 50 consists). Remark: The provisioning of electrical power is restricted to 50 consists (wagons) electrically connected to one traction unit, whereas the system limit for communication between consists is defined to be 104 vehicles (4 traction units, 100 wagons).

The inrush current resulting from powering up the Power Distribution Line (PDL) by the traction unit, shall be limited to allow a powering of up to 50 consists.

The negotiation of the request for higher power intake shall be done via the F-ETB.

The protocol for negotiation of higher power input shall be based on IEC 61375-2-3 (TCN communication profile).

The additional application specific protocol elements shall be defined in deliverable /WP5 D5.4/.

5.4.3.4. AC / DC converter

The AC/DC converter shall convert the 400 V AC (50 / 60 Hz) into DC voltages suitable for supplying the onboard devices and charging the battery.

This component is supplier specific.

All general electrical safety requirements to this component remain valid.

5.4.3.5. Battery charger

The battery charger charges the battery in a specific way, depending on the chemistry, capacity, temperature, etc. of the battery.

This component is supplier specific.

5.4.3.6. Battery Management System (BMS)

The BMS shall protect the battery against overcharging, over discharging, over current, overheating, perform cell voltage levelling, etc.

This component and its interface to the CCU is supplier specific.

The BMS shall provide overall diagnostics (e.g. state of charge, temperature) upon request to the CCU. The overall diagnostics to be provided shall be defined in /WP5 D5.4/.

This component and its interface to the CCU is supplier specific.

5.4.3.7. Energy storage (battery)

The energy storage shall supply the on-board systems with energy, when the PDL is without power (e.g. during shunting operations)

The energy storage shall supply high power to the so-called high-power devices (e.g.: uncoupling actuator, parking brake…).

The energy storage technology (chemistry, voltage, …) is supplier specify and thus not defined here.

The detailed requirements to the required capacity of the energy storage will be defined in /WP5 D5.4/.

5.4.3.8. LV DC Control & Monitoring (low power)

The provisioning of power to onboard devices other than the CCU, shall be done via the wagon side switch. This shall be done by providing 100BASE-TX ports being capable of IEEE 802.3af (Power-over-Ethernet). The available power for each device is limited to ~ 15 W per port, resulting about 12 W for the powered device (see IEEE 802.3af for details). Each port shall be able to be controlled by the CCU to switch on/off devices depending on state of the battery and functional importance of the device.

5.4.3.9. LV DC Control & Monitoring (high power)

The design of the control & monitoring of the LV DC supply is supplier specific.

The LV DC high power supply output shall provide high power devices (e.g.: uncoupling actuator) with nominal 48 V DC, 10 A for at least 6 seconds consecutively.

The LV DC high power output is proposed to be provided from the energy storage (battery) of the WPS. As the WPS is supplier specific, the provisioning of the defined power is up to the specific implementation.

5.4.3.10 Power Distribution Line monitoring

The Power Distribution Line (PDL) shall be monitored by a circuit to detect contact issues on the E-Coupler (power). The detailed requirements for the PDL monitoring will be defined in /WP5 D5.4/.

The implementation is supplier specific and thus not described in this document.

5.4.4 Brake system

All interfaces between CCU and brake components will be supplier and vehicle specific and are not defined in this document.

5.4.4.1 Brake Pipe monitoring

This section provides the list of requirements for the physical reference architecture components which will enable the monitoring of the Brake Pipe on each consist, as requested in section 9.3.17 of /WP3 D3.1/.

Since the Brake Pipe pressure remains the input for the distributors (even in case of the future EP-brake implementation), it is one of the main parameters to be checked to perform the diagnostics of the brake system.

The monitoring of Brake Pipe can be used also in the context of ABT for:

- Brake Pipe continuity check and (directly measuring the Brake Pipe pressure on each wagon along the train, besides checking the consequent state of the brakes)
- Leakage test (providing multiple points of measure instead of just the one on the Traction Unit)

Remark: in the future, when EP-brake will be implemented during Demo II, it will heavily rely on this measurement. Moreover, in the future extended brake monitoring functionalities can also make use of the Brake Pipe monitoring (e.g. brake diagnostics during running condition).

Each wagon shall be equipped with one or more pressure transducers installed on the Brake Pipe which enable the CCU to acquire the Brake Pipe pressure.

Rationale:

Even if the wagon is equipped with more than one distributor, it is sufficient to have only one value of the Brake Pipe pressure for the whole wagon.

The number and type of pressure transducers selected shall reach the safety level prescribed respectively by /WP4 D4.2/ and an accuracy suitable for the use of this function described in /WP5 D5.1/.

Rationale:

Since the Brake Pipe monitoring equipment is not considered interchangeable, the number and type of pressure transducers can be chosen by the suppliers as long as the above requirement is fulfilled.

The Brake Pipe pressure transducer(s) shall be installed directly on the Brake Pipe or in any case up-stream to any isolation device which isolates the brake system from the Brake Pipe (e.g. Distributor's isolating cock)

Rationale:

It must be possible to always monitor the Brake Pipe pressure directly, regardless of the isolation state of the brake system.

The physical link between each pressure transducer and the CCU shall reach the safety level for the function prescribed by /WP4 D4.2/.

Rationale:

Not only the sensor itself but also the physical connection between the sensor and the acquisition electronics (e.g. hardwired, communication bus, etc.) must be chosen in such a way that the overall detection function reaches the safety level prescribed.

The physical link between each pressure transducer and the CCU can be chosen by the suppliers as long as the above requirement is fulfilled.

5.4.4.2 Automated Brake Test

This section provides the list of requirements for the physical architecture components which will enable the ABT execution on wagon-set side.

A master – slave approach is considered, where the CCU of each consist is the slave electronic unit providing the information to the Master of ABT (e.g. CCU on Traction Unit) about the different states of brake system.

Following the general physical architecture approach, the equipment required to enable the ABT execution, and its interfaces are not considered neither interchangeable nor interoperable. Thus, each brake system supplier can choose the type, number, and location of sensors as long as the other requirements are satisfied (e.g. General requirements, Safety requirements, etc.).

On the other hand, the level of detail (per-consist / per brake group / per bogie) of the detection must be harmonised, so it is clearly specified in the below requirements.

The list follows the chronological order of operations as per the operational process TP09 "Automated Brake Test" described in /WP2 D2.1/ and /WP3 D3.1/.

Check of isolation state and G/P setting

The following requirements prescribe the necessity to include in the physical architecture the sensors required to enable the preliminary operations of checking the isolation state and G/P setting of the brake system (see activities TU9.15 and SD9.14).

	OPEID
Each consist shall be equipped with one or more sensors to enable the CCU to detect the "ON/OFF" (active/isolated) state of the brakes	TU9.15
In case of multiple brake groups in the same consist, the consist must be equipped with the number of sensors required to allow the CCU to detect the "ON/OFF" (active / isolated) status **on each brake group**	TU9.15

Rationale:

the distributor of each brake group installed on the consist can be isolated through a dedicated handle. It is therefore required to detect if any of the distributors has been isolated, before moving to the check of correct functioning of the brakes.

	OPEID

The number and type of sensors selected shall be such that the "ON/OFF" (active / isolated) detection reaches the safety level prescribed by D4.2 "Risk Assessment and harmonized safety architecture"	TU9.15 SD9.14

Rationale:

The type of sensor (e.g. microswitch on the handle or pressure transducer) might depend on the strategy and technical solution chosen by each supplier. The number of sensors depends not only by the number of brake groups installed but also by the reliability of the single sensor chosen.

The number and type of sensors can be chosen by the suppliers as long as the above requirement is fulfilled.

Each supplier can evaluate the best location of the sensors based on the strategy chosen for the detection. This strategy should be efficient and should try to re-use the same sensors for different steps of the ABT, thus minimizing the number of sensors required.

	OPEID
The physical link between each sensor and the CCU shall be such that the "ON/OFF" (active / isolated) detection reaches the safety level prescribed by D4.2 "Risk Assessment and harmonized safety architecture"	TU9.15 SD9.14

Rationale:

Not only the sensor itself but also the physical connection between the sensors and the acquisition electronics (e.g. hardwired, communication bus, etc.) must be chosen in such a way that the overall detection function reaches the safety level prescribed.

Hand brake state detection

The following requirements prescribe the necessity to include in the physical architecture the sensors required to detect the state of hand brakes before moving to the actual check of pneumatic brake application and release (see activity WWS9.16).

	OPEID
Each consist shall be equipped with one or more sensors to enable the CCU to detect the state of the hand brake **for each bogie or wheelset equipped with a hand brake**.	WWS9.16

Rationale:

The hand brake may affect the detection of the pneumatic brake (depending also on the type of sensors used to detect the pneumatic brake state). Moreover, some of the consists may be selectively required to have the hand brakes applied, in order to grant the immobilization of the complete train during brake test.

For these reasons, the ABT Operational Process requires to check first that the state of hand brakes is the one expected, before moving to the check of pneumatic brake.

	OPEID
The type of sensor (including its accuracy) and measured variable (e.g. stroke sensor or force sensor) shall be such that the hand brake state detection reaches the safety level prescribed by D4.2 "Risk Assessment and harmonized safety architecture"	WWS9.16

Rationale:

The type of sensor might depend on the design of the hand brake equipment currently installed on already existing consists and on the technical solution chosen by each brake system supplier to detect its state. The number of sensors depends not only by the number of hand brakes installed but also by the reliability of the single sensor chosen.

Since the pneumatic brake state will be detected on each bogie (per-bogie level detection), also the hand brake detection must provide the same level of detail: i.e. even in case of one hand brake mechanism actuating on multiple bogies, the information sent by the CCU to the Master of ABT must be per-bogie, not per-consist.

Whatever the type and number, the system must achieve the safety level target prescribed for the detection.

	OPEID
The location and number of the sensors shall be chosen by the supplier in order to allow the CCU to detect the status for **each bogie or wheelset equipped with the hand brake** according to the type of sensors chosen	WWS9.16

Rationale:

Each supplier shall evaluate the best location of the sensors based on the strategy chosen for the detection.

	OPEID
The physical link between each sensor and the CCU shall be such that the hand brake state detection reaches the safety level prescribed by D4.2 "Risk Assessment and harmonized safety architecture"	WWS9.16

Rationale:

Not only the sensor itself but also the physical connection between the sensors and the acquisition electronics (e.g. hardwired, communication bus, etc.) must be chosen in such a way that the overall detection function reaches the safety level prescribed.

Pneumatic brake state detection

The following requirements prescribe the necessity to include in the physical architecture the sensors required to detect the state of pneumatic brakes. The detected state will be used by the Master of ABT to check the coherence between brake request and brake actuation, which is the main purpose of the Brake Test (see activity WWS9.16).

	OPEID
Each consist shall be equipped with one or more sensors to enable the CCU to detect the state of the pneumatic brake for **each bogie**.	WWS9.21 WWS9.24

Rationale:

during the legacy manual brake test, the application/release state of the brakes is checked on each bogie by the operator. The same level of detail must be kept when moving to the ABT: i.e. **the information sent by the CCU to the Master of ABT must be per-bogie, not per-consist**, even in case of one brake cylinder per consist actuating the rigging of both bogies.

	OPEID
The type of sensor (including its accuracy) and measured variable (e.g. pressure transducer or force sensor) shall be such that the pneumatic brake state detection reaches the safety level prescribed by D4.2 "Risk Assessment and harmonized safety architecture"	WWS9.21 WWS9.24

Rationale:

The type of sensor might depend on the design of the bogie brake equipment currently installed on already existing consists and on the technical solution chosen by each supplier to detect its state. The number of sensors depends not only by the number of hand brakes installed but also by the reliability of the single sensor chosen.

	OPEID
The location and number of the sensors shall be chosen by the supplier in order to allow the CCU to detect the status for **each bogie** of the consist, according to the type of sensors chosen	WWS9.21 WWS9.24

Rationale:

Each supplier shall evaluate the best location of the sensors based on the strategy chosen for the detection.

	OPEID
The physical link between each sensor and the CCU shall be such that the pneumatic brake state detection reaches the safety level prescribed by D4.2 "Risk Assessment and harmonized safety architecture"	WWS9.21 WWS9.24

Rationale:

Not only the sensor itself but also the physical connection between the sensors and the acquisition electronics (e.g. hardwired, communication bus, etc.) must be chosen in such a way that the overall detection function reaches the safety level prescribed.

5.4.4.3 Automated Parking Brake requirements

This topic is not more in scope of this document because the functionality has been moved to Demo II. The chapter will be updated when the requirements will have been defined.

5.4.4.4 Network based EP-Brake requirements

This topic is not more in scope of this document because the functionality has been moved to Demo II. The chapter will be updated when the requirements will have been defined.

5.4.5 Push buttons / signal lamps for manual operation of DAC

The detailed architecture of the panel with push buttons and signal lamps for the manual operation of the DAC and the interface to the coupler and/or the CCU must be developed at a later phase within FP5 because operational procedures as well as detailed train functions for decoupling are still pending. The chapter will be updated when the requirements will have been defined.

5.4.6 Rear end signals

The requirements for rear end signal (e.g. tail lights) in an automated environment must be defined before the system physical system architecture can be developed

5.5. FDFTO Traction Unit Base System physical architecture

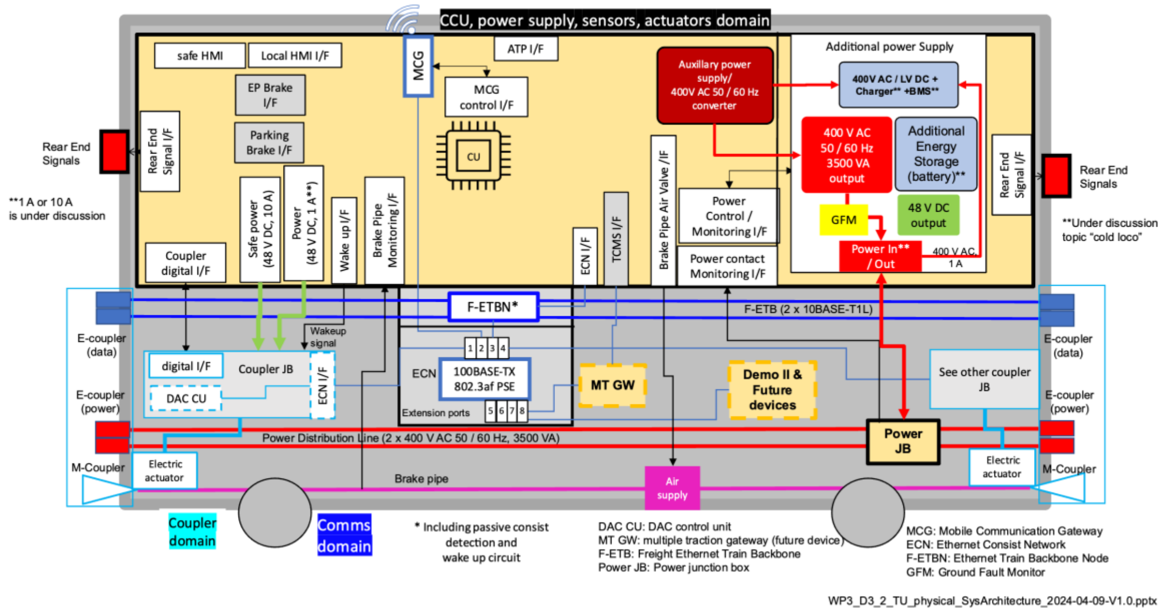

Figure 8: FDFTO Traction Unit Base System physical architecture

In the diagram above, the FDFTO traction unit base system physical architecture is shown. This FDFTO traction unit base system shall support all functional requirements as described in /WP3 D3.1/ by providing a consist internal communication system, a train-wide-communication system (the F-ETB), and a FDFT-Link (via MCG) for wireless information exchange with the landside FDFT systems.

In addition to communication, the power supply and the traction unit related further requirements are defined (e.g.: interface to main brake pipe, braking actuators, …).

The standardization of interfaces is restricted to those between the three domains (Coupler, Communication, CCU). All other interfaces can be implemented on a supplier specific approach, although the still following the general requirements as stipulated in chapter 5.7.

The requirements to the standardized interfaces are described hereinafter.

5.5.1. Coupler System

5.5.1.1. M-Coupler

This topic is covered in detail in /WP5 D5.2/ and described in this document covering the so-called coupler domain. There exists no direct interface with FDFT but indirectly via the coupler domain – CCU I/F.

The so-called hybrid coupler is not considered in this document: We consider only the DAC-part of this hybrid coupler, which shall behave identically to the DAC.

The hybrid coupler is described in /WP5 D5.2/.

5.5.1.2. E-Coupler

This topic is covered in detail by the /WP5 D5.2/. All aspects of mechanical layout, contacts selected, cover lid, … are transparent to the physical system architecture.

For the physical system architecture, the E-coupler is providing the means of interconnecting the power distribution line and the F-ETBN between the consists.

5.5.2 Consist Control Unit

The consist control unit of the traction unit shall host the train functions, which are defined in /WP5 D5.1/.

5.5.3 Traction Unit Power Supply System

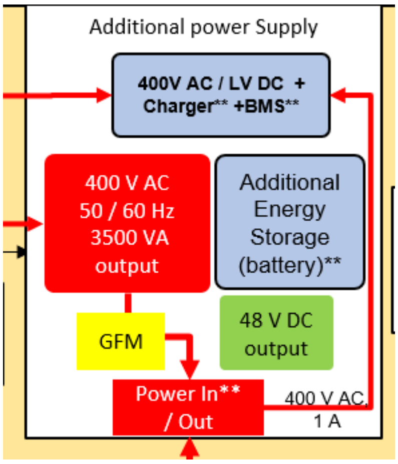

Figure 9: Traction Unit Power Supply system

The Traction Unit Power Supply System (TUPSS) is part of the CCU domain and thus is handled supplier specific.

5.5.3.1 Power Management Control Interface

This interface between the CCU and the TUPSS is supplier specific and thus not described in this document.

5.5.3.2 Power Management

The power management is supplier specific. The functional requirements from /D3.1/ shall be fulfilled.

5.5.3.3 Input 400 V AC

This interface is supplier specific and thus not described here.

The maximum standard power input into the TUPSS shall be restricted to 50 W.

The TUPSS shall ensure, that this standard power input isn't exceeded.

The TUPSS shall work safely with power supplied over the power distribution line having the nominal voltage of 400 V AC.

The TUPSS shall support to work with a power frequency being at 50 Hz or 60 Hz nominal. Both frequencies shall be supported.

Rationale: If the power available at the PDL is supplied by a traction unit it might have a nominal frequency of 60 Hz, whereas if the power is provided by a grid it has a nominal frequency of 50 Hz.

The TUPSS shall be able to accept more power from the PDL upon remote request (for future use).

The protocol for negotiation of higher power input shall be based on IEC 61375-2-3 (TCN communication profile).

Rationale: This functionality gives the opportunity to recharge batteries faster, when more power for each consist is available (e.g.: traction unit hauling less than 50 consists).

The inrush current resulting from powering up the Power Distribution Line (PDL) by the traction unit, shall be limited to allow a powering of up to 50 consists.

The detailed requirements to the TUPSS will be defined in /WP5 D5.4/.

The additional application specific protocol elements shall be defined in /WP5 D5.1/.

5.5.3.4 AC / DC converter

The AC/DC converter shall convert the 400 V AC (50 / 60 Hz) into DC voltages suitable for supplying the onboard devices and charging the battery.

This component is supplier specific.

All general requirements (e.g.: electrical safety, overvoltage protection, ...) to this component shall be considered.

Remark: It isn't decided yet if this component will have to be provided. This depends on the decision about 5.8. Open topics, Behaviour of a "dead" traction unit in a freight train.

5.5.3.5 Battery charger

The battery charger charges the battery in a specific way, depending on the chemistry, capacity, temperature, ... of the battery.

This component is supplier specific.

5.5.3.6 Battery Management System (BMS)

The BMS shall protect the battery against overcharging, over discharging, over current, overheating, perform cell voltage levelling, etc.

This component and its interface to the CCU is supplier specific.

The BMS shall provide overall diagnostics (e.g. state of charge) upon request via the CCU to the requesting entity (e.g. traction unit, FDFT backend). Details will be defined in /WP5 D5.4/.

This component and its interface to the CCU is supplier specific.

5.5.3.7 Energy storage (battery)

The energy storage is needed to supply the on-board systems with energy, when the PDL is without power.

The energy storage is needed to supply high power to the so-called high-power devices (e.g.: uncoupling actuator, parking brake…).

The energy storage technology (chemistry, voltage, …) is supplier specify and thus not defined in this document.

The detailed requirements will be defined in /WP5 D5.4/.

5.5.3.8 LV DC Control & Monitoring (low power)

The provisioning of power to onboard devices other than the CCU, shall be done via the wagon side switch. This shall be done by providing 100BASE-TX ports being capable of IEEE 802.3af (Power-over-Ethernet). The available power for each device is limited to ~ 15 W per port, resulting in about 12 W for the powered device (see IEEE 802.3af for details). Each port shall be able to be controlled by the CCU to switch on/off the power to devices depending on state of the battery and functional importance of the very device.

5.5.3.9 LV DC Control & Monitoring (high power)

The design of the control & monitoring of the LV DC supply is supplier specific.

The LV DC high power supply output shall provide high power devices (e.g.: uncoupling actuator) with nominal 48 V DC, 10 A for at least 6 seconds consecutively.

The LV DC high power output is proposed to be provided from the energy storage (battery) of the WPS. As the WPS is supplier specific, the provisioning of the defined power is up to the specific implementation.

5.5.3.10 High Power Output 400 V AC / 3500 VA

The Traction Unit shall supply the Power Distribution Line (PDL) with electrical power to allow using the FDFT devices on board of the consists and to re-charge their batteries.

The power output from the traction unit power supply system to the power distribution line shall be at least nominally 3500 VA.

The output voltage of the power supply shall be nominally 400 V AC.

The output frequency of the power supply shall be nominally either 50 Hz or 60 Hz.

The output power supply to the PDL shall be monitored by a Ground Fault Monitor (GFM) to detect isolation faults or residual current flow.

The detailed requirements to the power supply will be defined in /WP5 D5.4/.

5.5.3.11 Power Distribution Line monitoring

The PDL shall be monitored by a circuit to detect contact issues on the E-Coupler (power). The implementation is supplier specific and thus not described in this document.

The detailed requirements will be defined in /WP5 D5.4/.

5.5.4 Brake system

All interfaces between CCU and brake components will be supplier specific and not defined in this document.

5.5.4.1 Brake Pipe monitoring

This section provides the list of requirements for the physical reference architecture components which will enable the monitoring of the Brake Pipe on each consist, as requested in section 9.3.17 of /WP3 D3.1/.

Since the Brake Pipe pressure remains the input for the distributors (even in case of the future EP-brake implementation), it is one of the main parameters to be checked to perform the diagnostics of the brake system.

The monitoring of Brake Pipe can be used also in the context of ABT for:

- Brake Pipe continuity check and (directly measuring the Brake Pipe pressure on each wagon along the train, besides checking the consequent state of the brakes)
- Leakage test (providing multiple points of measure instead of just the one on the Traction Unit)

Remark: in the future, when EP-brake will be implemented during Demo II, it will heavily rely on this measurement. Moreover, in the future extended brake monitoring functionalities can also make use of the BP monitoring (e.g. brake diagnostics during running condition).

Each wagon shall be equipped with one or more pressure transducers installed on the Brake Pipe which enable the CCU to acquire the Brake Pipe pressure

Rationale:

Even if the wagon is equipped with more than one distributor, it is sufficient to have only one value of the Brake Pipe pressure for the whole wagon.

The number and type of pressure transducers selected shall reach the safety level prescribed respectively by /WP4 D4.2/ and an accuracy suitable for the use of this function described in /WP5 D5.1/.

Rationale:

Since the Brake Pipe monitoring equipment is not considered interchangeable, the number and type of pressure transducers can be chosen by the suppliers as long as the above requirement is fulfilled.

The Brake Pipe pressure transducer(s) shall be installed directly on the Brake Pipe or in any case up-stream to any isolation device which isolates the brake system from the Brake Pipe (e.g. Distributor's isolating cock)

Rationale:

It must be possible to always monitor the Brake Pipe pressure directly, regardless of the isolation state of the brake system.

The physical link between each pressure transducer and the CCU shall reach the safety level for the function prescribed by /WP4 D4.2/.

Rationale:

Not only the sensor itself but also the physical connection between the sensor and the acquisition electronics (e.g. hardwired, communication bus, etc.) must be chosen in such a way that the overall detection function reaches the safety level prescribed.

The physical link between each pressure transducer and the CCU can be chosen by the suppliers as long as the above requirement is fulfilled.

5.5.3.2 Automated Brake Test

On the traction unit, only the CCU including an HMI are involved in the automated brake test, no ABT related sensors are available.

A master – slave approach is considered, where the CCU of each consist is the slave electronic unit providing the information to the Master of ABT (e.g. CCU on Traction Unit) about the different states of brake system.

A traction unit shall be able to participate to the brake test even the equipment that is used belongs to a legacy system (TCMS)

5.5.3.3 Automated Parking Brake requirements

This topic is not more in scope of this document because the functionality has been moved to Demo II. The chapter will be updated when the requirements will have been defined.

5.5.3.4 Network based EP-Brake requirements

This topic is not more in scope of this document because the functionality has been moved to Demo II. The chapter will be updated when the requirements will have been defined.

5.5.5 Push buttons / signal lamps for manual operation of DAC

The detailed architecture of the panel with push buttons and signal lamps for the manual operation of the DAC and the interface to the coupler and/or the CCU must be developed at a later phase within FP5 because operational procedures as well as detailed train functions for decoupling are still pending. The chapter will be updated when the requirements will have been defined.

5.5.6 Rear end signals

The requirements for the control of the already existing rear end signals in an automated environment must be defined before the system physical system architecture can be developed.

5.5.7 CCU – ATP I/F

The interface shall be used for forwarding the information with respect to the train length and train integrity from the CCU to the ATP device at high safety level.

Rationale: The ATP device shall provide train length information to the ground with SIL 4 and train integrity information with SIL 2. This requirement is based on the proposal from ER JU FA5 System Pillar WP3.1 FDFTO/ERTMS - Train Integrity and Train Length.

This interface between CCU and ATP will be supplier specific and not described here in detail but is assumed to be an Ethernet based message exchange.

5.5.7 CCU – TCMS I/F

The interface shall be used for exchange of information between CCU and the TCMS at required safety level.

This interface between CCU and TCMS will be supplier and vehicle specific and not described here in detail but is assumed to be a 100BASE-TX Ethernet based interface. If the existing TCMS I/F uses another connection type, an appropriate gateway would be needed to convert the information into 100BASE-TX based messages.

5.6 Common Interfaces

These interfaces are used commonly for wagons as well as for traction units.

5.6.1 Coupler domain – CCU

The CCU shall support two interface approaches for communicating with the coupler domain. This has been agreed to gather experience in upcoming field trials before the final decision for one of both interface approaches will be taken.

5.6.1.1 Network-based interface

The network-based interface shall be IEEE 100BASE-TX based and make use of the ECN switch provided by the F-ETBN.

In addition to the network-based interface, the following connections are needed:

- Low voltage low power supply (48 V, 1 A) of the DAC CU
- Low voltage high power supply (48 V, 10 A, 6 s) for actuation of coupler actuator

5.6.1.2 Digital signal-based interface

All digital signals as listed in "Table 1: DAC 5 Digital interface connections" shall be exchanged between the CCU and the coupler junction box.
Remark: The table is based on the input from the work packages WP6 – WP8.

The interface signals that shall be supported by the CCU and the coupler section are listed in the table below.

The detailed description of the signals and the signalling pulses is to be defined in /WP5 D5.1/

Table 1: DAC 5 Digital interface connections

Interface signals / cases	Pin count	Connector	Remark
Transit lines through the electrical coupler:			
4* SPE incl. neighbour detection	4	X5	
4* Power Line 400VAC	4	X9	
Reserve signals needed?	?		tbd.
Interface signals and energy supply at each coupler:			
Electrical Power 48 VDC input (power save mode dependent)	1	X8	
Electrical GND input	1	X8	
Safe Power 48 VDC input - decoupling actuation	1	X6	
Safe GND input - decoupling actuation	1	X6	
Monitoring mechanically coupled (2 x signal, 2 x power)	4	X6	
Monitoring mechanically (uncoupled and) ready to couple position (2 x signal, power will be taken from signal above)	2	X6	
Reserve sensor (2 x signal, power will be taken from signal above)	2	X6	

Monitoring Hybrid coupler position (not used on wagons) UIC mode (2 x signal, 2 x power)	4	X6	only for hybrid coupler
Monitoring Hybrid coupler position (not used on wagons) DAC mode (2 x signal, power will be taken from signal above)	2	X6	only for hybrid coupler
Monitoring Hybrid locked (2 x signal, power will be taken from signal above)	2	X6	only for hybrid coupler
Activation of coupler actuator to decouple + prevent coupling	2	X8	
Activation of coupler actuator to ready to couple position	2	X8	
Ethernet Consist Network (100BASE-TX)	4 +	X7	+ Shielding required
Push-Button Box (2 push buttons antivalent) input	6	X4	tbd.
Permanent power 48 VDC input	2	X8	tbd.

5.6.2 Communication System

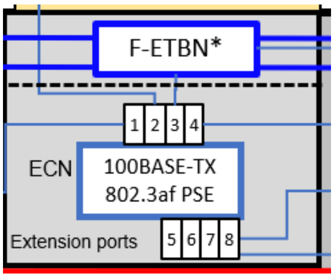

Figure 10: F-ETBN interfaces*

The F-ETBN* interfaces consist of:
(remark: * denotes that the F-ETBN features are part of IEC 61375-2-3:2024. The Committee Draft (CD) is planned to be published in summer 2024. The relevant additions are stipulated here:

- New subclause 6.9: wakeup process
- New subclause 6.10: passive wagon detection process
- New Annex part E.3.5: CCU-ETBN Interface for Wakeup control
- New Annex part E.3.6: CCU-ETBN Interface for passive wagon detection control
- New Annex part E.6.5: CCU-ETBN Interface for inserting a TLV packet (which itself is defined in Annex J) into HELLO frames
- New Annex part E.6.6: CCU-ETBN Interface for reading a TLV packet (which itself is defined in Annex J) inserted into received HELLO frames
- Annex J: Background information about freight trains, specification of automatic decoupling process

F-ETBN – CCU interface

- allowing the CCU to configure the F-ETBN and to get the detected train consist information from the F-ETBN
- F-ETBN includes the „passive consist detection circuit“
  acc. to IEC 61375-2-3:2024 chapter 6.10
- F-ETBN includes the provisioning of the “wake-up signal” to the CCU acc. to IEC 61375-2-3:2024 chapter 6.9

- F-ETBN – ECN interface
  - This Ethernet based interface shall be provided to allow the DAC CU of the coupler domain to communicate with the CCU
  - Ethernet extension ports shall be provided to support upgradability of the vehicle with so-called future devices. All future devices shall be provided with Ethernet based communication to the ECN while being powered thru IEEE 802.af ports (PSE) from the ECN switch.

5.6.2.1 F-ETB (Ethernet Train Backbone)

5.6.2.1.1 General

This section defines the in-train communication system which is responsible for interoperable data exchange between consists over the Freight Ethernet Train Backbone (F-ETB) based on Single Pair Ethernet (SPE) technology. It does not specify consist local functions and consist local interfaces which don't affect the interoperable F-ETB data communication as for example interfaces to local subsystems or IO devices. The latter should be subject of the related consist communication subsystem specification (WP5).

The Freight Ethernet Train Backbone (F-ETB) is the connection of Freight Ethernet Train Backbone Nodes (F-ETBN) based on switched technology using a redundant, aggregated transmission media as defined in IEC 61375-1 each consist contains at least one F-ETBN. Critical consists like leading locomotives could host 2 F-ETBN for improved availability. A minimum of one and a maximum of 127 F-ETBN shall be supported.

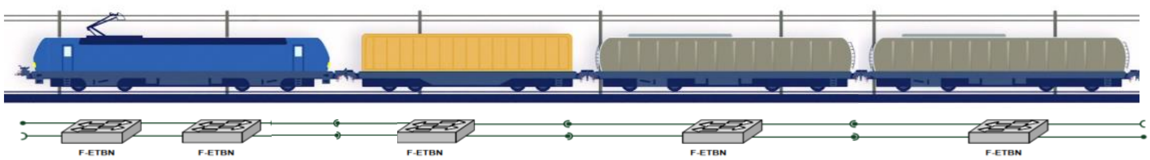

Figure 11: Freight Ethernet Train Backbone (acc. to IEC 61375-1)

5.6.2.1.2 FDFTO Physical Communication System architecture

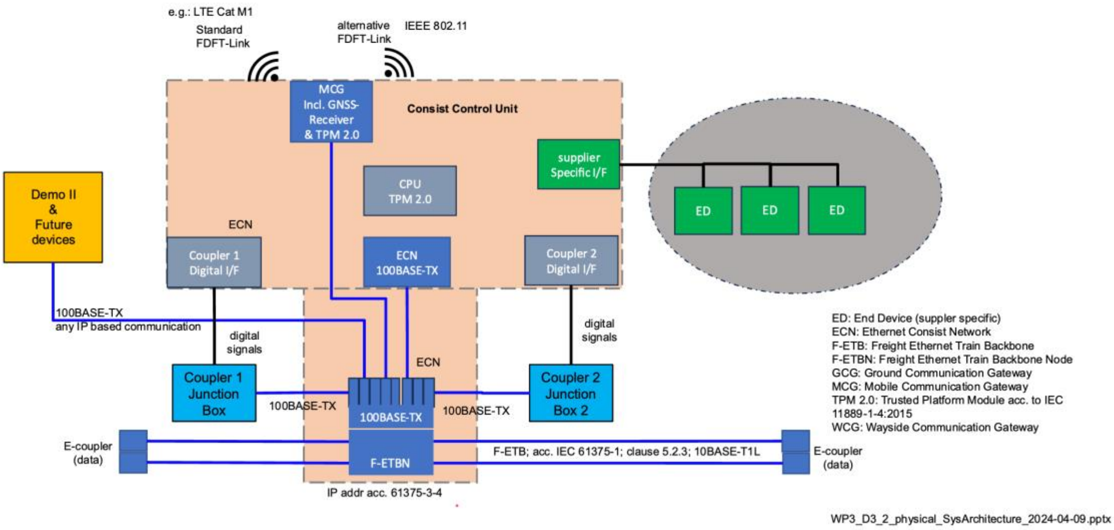

Figure 12: FDFTO Physical Communication System architecture

A reference architecture of a freight wagon communication subsystem is shown in Figure 12: FDFTO Physical Communication System architecture. Central component is the F-ETBN, which connects the consist network with the train communication backbone (F-ETB). Consist local subsystems are interconnected via the consist network. The Consist Control Unit (CCU) hosts the train functions and controls the F-ETBN.

A list of all components, which together establish the communication system, is presented in Table 2: Communication system components.

Note that the communication system architecture in locomotives might be different. Reason is that many locomotives have already a control infrastructure, and the F-ETB is an add-on which needs to be integrated with the existing control system. As this is a special case highly dependent on the locomotive type this is not further detailed here. Nevertheless, the interfaces and functions defined herein are valid for locomotives as well, independent from the architecture.

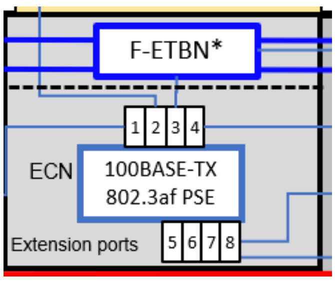

Figure 13: F-ETB Subsystem

Table 2: Communication system components

Component	Description
F-ETB	Freight Ethernet Train Backbone with cables and connectors.

F-ETBN	The Freight Ethernet Train Backbone Node (F-ETBN) connects the onboard devices and subsystems to the SPE-based Ethernet Train Backbone (F-ETB).
	Basic functions of the F-ETBN are:
	• Train Network Discovery as defined in IEC 61375-2-5
	• Forwarding of Ethernet frames along the F-ETB (IEEE 802.1Q bridging)
	• Bypass in case of defective F-ETBN or powerless consist (passive consist)
	• IP packet routing between ECN and F-ETB
	• Train Composition Detection as defined in IEC 61375-2-3 including:
	  ○ Set/reset “leading”
	  ○ Train composition confirmation
	  ○ Train composition correction
	  ○ TTDB computation
	• Support of wake-up function
	• Support of passive consist detection
	• Optional: IP packet filtering (firewall)

Ethernet Consist Network (ECN)	Consist local Ethernet network compliant to IEC 61375-3-4 (100BASE-TX).
CCU (Consist Control Unit)	Processing unit for train functions (list not exhaustive): ▪ train composition validation ▪ control of passive consist detection ▪ train integrity supervision ▪ train length determination ▪ control of wake-up function ▪ automatic brake test ▪ automated uncoupling ▪ ...
MCG	Mobile Communication Gateway for train-to-ground communication
DAC	E-Coupler
DAC CU	DAC Control Unit. Controls DAC actuators and processes input from related sensors

5.6.2.1.3 Interfaces

To support consist interoperability and component exchangeability, a set of generic, well-defined interfaces must be specified and standardized. Besides those generic interfaces there might be local interfaces, typically for connecting subsystems or sensors/actuators, which are CCU design specific.

A list of generic interfaces is provided in Table 3: Generic communication system interfaces.

Table 3: Generic communication system interfaces

Interface	Description
F-ETB Interface	Physically, the F-ETB interface defines the interface between the F-ETBN and the F-ETB. Logically, it defines the interface between consists. For consist interoperability, mechanical detachability, electrical connectivity, and data communication connectivity have to be ensured. Data connectivity is specified with IEC61375-2-5 and IEC61375-2-3 for the communication layers (lower OSI layers). Application data itself are specified with freight train specific application profiles. Only the specification of the communication layers is in F-TCN scope.
E-Coupler Head Interface	This is the mechanical interface between E-couplers
Junction Box interface	Interface to sensors within the junction box (e.g., current sensors for the forked power line).
DAC CU Interface	This interface is used to read sensor data like coupling state or to drive actuators like the actuator used for safe decoupling.
Subsystem Interface	Interface to local subsystems (optional)
I/O Interface	Local IO channels (optional)

5.6.2.1.4 Functions

There are a set of functions which the communication system has to provide or to support. The hardware related functionality is listed in Table 4, whereas the data related functionality is described in D3.3.

Table 4: Communication system functions

Function	Description
Support Ethernet Communication	Basic network function for propagating Ethernet frames within a OSI Layer 2 network (like F-ETB or F-ECN). This function is based on IEEE 802.1Q and deals with: ▪ frame relaying and forwarding ▪ link aggregation ▪ Quality of Service (QoS) ▪ Unicast/multicast Virtual LAN
Support F-ETB Bypass	F-ETBN shall be automatically bypassed in case of power-failure or a device defect.
Provide power to End Device (ED)	Power over Ethernet (PoE, IEEE 802.3af/at) and Power over Dataline (PoDL, IEEE 802.3bu) is a feature which can be used to provide power to local end devices like sensors or actuators over the Ethernet cable.
Support F-ETB Control	These are functions for train inauguration control like: • Wakeup request • Passive consist detection control These functions are specified in IEC 61375-2-3 Annex E.

5.6.2.1.5 F-ETB Redundancy management

Redundancy of network components shall prevent a network outage in case of a single network failure. Network failures to be covered are:

- Ethernet link loss (disruption of cable, transceiver failure, E-coupler connector failure)
- Network device failure

These are discussed in the next sections.

5.6.2.1.5.1 F-ETB Link redundancy

As Ethernet is a segmented network and no bus, a single F-ETB link failure will affect only one Ethernet segment. Multiple F-ETB faults will not lead to a communication loss as long as not both F-ETB lines of one Ethernet segment are disturbed.

Link redundancy of one Ethernet segment shall be handled by using link aggregation as defined in IEEE 802.1AX. Although this is a data related functionality, the chipset used for Ethernet switching shall include this functionality.

5.6.2.1.5.2 F-ETBN redundancy

Currently it is not planned to use redundant F-ETBN. This might change, when the requirements out of the safety analysis are described to a more detailed level. /WP 4 D4.2/.

5.6.2.1.6 F-ETB Performance

An important aspect of the communication system are requirements related to quantities and performance values. The following system limits shall be supported by the communication system, as listed in Table 5.

Table 5: Communication system physical aspects

Parameter	Value	Comment
Maximal F-ETB length	2500 m	Due to meanders the cable length per vehicle is about 150 % of the vehicle length (see IEC 61375-2-1 subclause 4.1.5), and maximal train length is 1670 m.
Maximal number of consists	104	100 wagons + 4 locomotives
Maximal number of F-ETBN	127	Some Locos/wagons may have 2 F-ETBN for redundancy
Maximum number of subsequent passive consists to be detectable	Approx. 15	As defined in IEC 61375-2-3 upcoming version as of April 2024

5.6.2.2. FDFT Link Gateway (MCG)

5.6.2.2.1 Basic design and hardware

A physical Mobile Communications Gateway (MCG) shall be implemented on each consist. No redundant implementation of MCGs on a consist is planned. No redundancy between MCGs in a train is planned.

The concept of Train to ground communications shall follow IEC 61375-2-6. If there are options in this normative, either a recommendation or a decision on the way to follow the normative is given in this document.

The MCG shall be connected to the Freight Ethernet Train Backbone Node (F-ETBN) via Fast Ethernet IEEE 802.3 100BASE-TX.

The MCG shall support to be powered through Power over Ethernet acc. to IEEE 802.3af.

The MCG shall allow communication using the Ethernet Consist network (ECN).

A Trusted Platform Module (TPM) shall be included physically into the MCG to securely store authentication keys.

The TPM of the MCG shall support TPM 2.0. acc. to ISO/IEC 11889-1:2015.

On ERA's request, a GNSS module shall be foreseen for providing time synchronization and geo position data.

Description	Reference to IEC 61375	Justification / Rationale
A physical Mobile Communications Gateway (MCG) shall be implemented on each consist to provide FDFT Link functionality.		To provide the functionality of the Wireless FDFT-Link, a physical FDFT-Link Gateway shall be provided. It shall be called Mobile Communications Gateway (MCG).
The MCG sub-system shall meet the elements shown in IEC 61375-2-6, chapter		

4.4.3, table 3.		
The MCG shall be installed as part of every CCU or as a separate device attached to the CCU.		
The power supply of the MCG shall be provided via Fast Ethernet PoE (IEEE 802.3af) by the Train Backbone Node (TBN).		In case the device is physically a separate device, it shall support PoE power.
The MCG is connected to the ECN (Ethernet Consist Network) for onboard communications.		VLANs are used to separate communication profiles.
For Train to ground communication the requirements shown in IEC 61375-2-6, chapter 4.2, table 1 shall be met. Exceptions to table 1 are noted in the reference to this requirement.	<Reference the next 2 requirements>	
No redundancy through another MCG located on another consist in the same train shall be considered, as mentioned in IEC 61375-2-6, chapter 4.2, table 1, row 6.	As a reference see <X1>	IEC 61375-2-6 chapter 4.2, table 1, row 6 states a redundancy option using a MCG located in another consist.
Multiple MCGs shall not be considered as mentioned in IEC 61375-2-6, chapter 4.2, table 1, row 5.	As a reference see <X1>	IEC 61375-2-6, chapter 4.2, table 1, row 5 states a redundancy option, which is not required. MCG is neither required for redundancy nor for load balancing as

		most other components are not redundant either. To save costs.
The MCG shall consider a way to reflect upgrades to mobile radio technology without the need to replace the whole MCG, as mobile networks evolve.	Provide a way to upgrade from LTE to 5G without replacing the whole system.	
A trusted platform module (TPM) shall be included in the MCG hardware to securely store authentication keys.		
The TPM technology and security level shall be state-of-the-art. TPM 2.0 is minimum.		
A GNSS (Global Navigation Satellite System) receiver shall be implemented in the MCG.		We received a request from ERA for a future requirement to equip each consist with a GNSS receiver.
The GNSS receiver shall be state-of-the-art.		

5.6.2.2.2 FDFT Link Mobile Communication

The MCG shall provide connectivity via Public Mobile Communications Network or Wireless LAN (bearers) to wayside systems, herein referred as Ground Communications Gateway (GCG) and Wayside Communications Gateway (WCG), to provide connectivity to FDFT Backend systems.

The MCG shall meet all the requirements for bearers.

For mobile communication networks, low power communication options shall be used, if they are provided by the networks.

The services provided by the MCG shall be always available to the FTFD backend systems via the FDFT link, therefore the FDFT Link shall be available at any time. MCG

Train Wake-up shall be implemented to ensure communications and wake up at any time.

Requirement ID	Description	Justification / Rationale
	For the MCG a public cellular network (mobile network) shall be used to provide the data connection (bearer).	
	A Wireless LAN (Wi-Fi network) shall be used as addition to public cellular network (bearer).	
	Wireless LAN shall be implemented according to standard IEEE 802.11.	2.4 GHz frequency as general option
	The MCG shall not use wireless communication standards for railway communication and applications (GSM-R / LTE-R) or any FRMCS based technology.	MCG uses solely public mobile network or Wireless LAN instead.
	The public cellular network technology shall be state-of-the-art.	Currently, this would mean LTE (4G, 4th generation) as a minimum requirement for cellular network. For future use 5G and evolving technologies shall be considered.
	A substandard offering machine-to-machine (M2M) communication shall be supported by the MCG. Specifically, this means LTE-M (LTE Cat-M1) for 4G public cellular networks.	This is sufficient for low bandwidth requirements and has the effect of saving power.
	If the public cellular network is capable of LTE Cat-M1, it shall be preferred by the MCG.	Prefer use of low power technology. LTE Cat-M1 offers bandwidth from 300 kbit/s up to 1 Mbit/s.
	In 5G public cellular network, low power option shall	Prefer use of low power technology;

	be preferred (NB-IoT 5G or similar).	the standard is still evolving
	If 4G and 5G public cellular network are unavailable, an option should be provided to fall-back to 2G technology.	This is an option to provide better network coverage. 2G network will likely not play a big role beyond year 2027.
	Each entity using the FDFT Link communication shall consider the available bandwidth for LTE Cat-M1 (from 300 kbit/s up to 1 Mbit/s).	
	Each entity using the FDFT Link communication shall consider the latency for LTE Cat-M1 (typical value of 10 - 15 ms).	Source: 3GPP Release 13
	The functionality of a SIM card for public cellular network authentication shall be included.	eSIM (embedded SIM card) is preferred
	The SIM card shall provide data roaming capability for public cellular networks.	
	An MCG Train Wake-up Service as described in IEC 61375-2-6, chapter 6.3.6 shall be implemented to ensure continuous communication capability and wake up.	Even when the consist is in energy saving mode.

SL 4 – Prevent the unauthorized disclosure of information to an entity actively searching for it using sophisticated means with extended resources, IACS specific skills and high motivation.
Remark: In the current situation, SL4 is the expected required security level.

The authentication keys shall be securely stored in a hardware TPM (Trusted Platform Module).

The MCG shall provide network connectivity and data services from and to the consist via Radio interfaces.

The MCG shall provide basic services to subsystems on the consist, like time source and geo position information through a GNSS module.

5.7. General requirements

The requirements described hereinafter, might be dependent on the type of consist (traction unit, wagon) and of the geographical region, industrial areas (ATEX) where the consists are running. The specialized requirements are tagged accordingly.

The general requirements to the FDFT system are independent of the actual functionality to be provided by the system but are influencing it and thus shall be considered when developing components, sub-systems, and interfaces.

5.7.1. Environmental conditions

The environmental conditions for all onboard devices that are installed on the outside of a consist, shall be assumed according to the operational needs of the consist (climate zone, ATEX, salt water, dirt, dust, …).

The environmental conditions, which shall be supported by the FDFT equipment are defined in EN 50125-1 and depend on the geographical area the vehicles are planned to be used. As the vehicles, equipped with DAC/FDFT related devices are traveling throughout Europe, the related environmental classes are selected.

5.6.1.1 Temperature

All devices shall support being operated in the air temperature range of class of the consist where installed, acc. to EN 50155:2021, table 1. This includes the accumulator / batteries being used.

5.6.1.2 Humidity

All devices shall support being operated in the humidity range as defined in chapter 4.4 of EN 50125-1:2014.

5.6.1.3 Altitude

All devices shall support being operated in an altitude between

-150 m (within Channel Tunnel, -115 m) and more than 1400 m including the following tracks:

- Gotthard (Switzerland): 1151 m,
- Brenner (Italy): 1371 m,
- Semmering (Austria): 985 m,
- Finse: (Norway): 1222 m.

This results in an Altitude class AX according to table 1 of EN 50125-1. This is relevant for both tightness & supporting of cooling by convection or ventilation.

5.6.1.4 Air movement

All outdoor devices shall support being operated in a windy environment with wind speeds up to 35 m/s. The additional wind speed, generated by the travelling speed of the consist shall be considered.

5.6.1.5 Rain

All outdoor devices shall support being operated in a rain rate of up to 6 mm/min concurrent to the occurring wind speed and vehicle movement.

5.6.1.6 Snow and hail

All outdoor devices shall support being operated in an environment, where snow and hail is expected. This shall include the requirements for class 3, from table 3 – classes of snow levels of EN 50125-1:2014.

5.6.1.7 Ice

All outdoor devices shall support being operated in an environment, where ice forming and falling shall be assumed.

5.6.1.8 Solar radiation

All outdoor devices shall support being operated in an environment, where solar radiation occurs acc. to class R2 (high) of table 4 of EN 50125-1:2014.

5.6.1.9 Lightning

All outdoor devices shall support being operated in an environment, where effects of lightning on the vehicle occur. For protection against lightning on the vehicle refer to EN 50124-2

5.6.1.10 Pollution

All outdoor devices shall support being operated in an environment, where pollutions occur.

The list of substances that shall be assumed, are listed in chapter 4.11 of EN 50125-1:2014.

5.6.1.11 Large animals on track

All outdoor devices shall support being operated in an environment, where large animals are expected to be on track, acc. to chapter 4.12 of EN 50125-1:2014.

5.7.2 Weight

The overall requirement is that the weight of a consist (wagon) should not be higher than before having it equipped with onboard devices and DAC. This is related to the state, where the previously existing screw couplers and buffers have been dismounted.

Remark: If the overall requirement can't be fulfilled, additional weight shall be reduced as much as possible.

For traction units it shall be considered that they might have to have a hybrid coupler which requires to have the buffer remaining installed.

5.7.3 Dimensions

The dimensions of the outdoor devices of vehicles shall not infringe the structure gauge as given by the infrastructure (e.g.: as given by wayside elements, bridges, tunnels, …).

5.7.4 Mounting

The mounting of outdoor devices onto vehicles shall not infringe the structure gauge as given by the infrastructure (e.g.: as given by wayside elements, bridges, tunnels, ...).

5.7.5 Safety related requirements

In /WP4 D4.2/ "Risk assessment and harmonized safety architecture" the potential hazards that a DAC-fitted FDFT could lead to are identified and analysed. This process uses the results of /WP2 D.2.1/ "Preliminary operational procedures" as input. The result of this analysis being a HAZOP (Hazard and Operability) table that is an appendix of /WP4 D4.2/.

The main results of this work are the safety related requirements that are given in the following table.

Table 6: Safety requirements and related TFFRs

TFFR	Safety Requirement
10^{-9}	The brake pipe must be continuous during the train- run.
	Unintended decoupling / train separation during the train run without opening the brake pipe must be prevented. If a local decoupling mechanism is introduced, the same safety requirement as for the central decoupling function applies. Unauthorized access must be prevented.
	Speed and brake distance related data must be provided correctly to ATP.
	Untimely inhibition of the pneumatic brake must be avoided.
	Without trackside line occupied monitoring, decoupling / train separation without information to the ATP must be avoided.
	Without trackside line occupied monitoring, train length determination must be provided correctly.
10^{-7}	Unwanted decoupling, decoupling of wrong waggon in a protected area must be avoided.
	The parking brake must not be released untimely in a protected area.
	The brake percentage must be provided to the loco (on board channel) in a protected area.
	A single wagon must brake when commanded.
10^{-6}	Indicate applied brakes during train run. Apply EP brake or parking brake only on a valid command from the leading vehicle. Don't apply power if contacts are not coupled or covered.
	Indicate malfunction of coupling and exceedance of force limits to operator.
	Indicate "lost" wagons to operator and / or ATP (automatic train protection).
	Switch on end of train signal at the end of the vehicle being at end of train.
	Supply train with power during train run.

In addition to the requirements listed in the Table above the following technical requirements can be considered obligatory from a safety point of view:

- The coupling must be able to cope with the most extreme infrastructure without damage (horizontal and vertical radius, track twisting).
- Deformation of the absorber elements must be indicated.
- No single failure must lead to an unwanted closure of the brake pipe.
- Prevent penetration of foreign matters and water into the brake pipe.

In these cases, no TFFR can be assigned as TFFR is not defined for mechanical systems.

Safety requirements are partially dependent on a specific design. In some cases, the responsibility is shared between an operational and a supervision channel. This means, that the requirements and even the hazard analysis must be checked and revised in respect to the final design.

Remark: The hazard log and who is in charge in resolving the consequences, e.g. EU agency if it is done by national safety authorities, or who is in charge, is currently discussed with the ERA and the NSAs.

The supervision aspect (vehicles and operations) is addressed by law to the NSAs. This shall be considered in upcoming releases of /WP4_D4.1/ and /WP4_D4.2/.

5.7.6 Electromagnetic compatibility

Regarding electromagnetic effects the following standards apply:

- EN 50500 “Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure”.
- EN 50121 “Railway applications - Electromagnetic compatibility” – all parts
- EN 50238 “Railway applications – Compatibility between rolling stock and train detection systems”
- EN 50592 “Railway applications - Testing of rolling stock for electromagnetic compatibility with axle counters”
- EN 50617 “Railway Applications - Technical parameters of train detection systems for the interoperability of the trans-European railway system “– all parts
- EN 50728 “Railway applications - Rolling stock - Testing of rolling stock for electromagnetic compatibility with track circuits.”

5.7.7 Fire protection

All devices shall be compliant with the requirements out of /TSI WAG/ or with the requirements out of EN 45545.

5.7.8 ATEX

If devices / components are to be installed onto vehicles that enter so called ATEX restricted zones, they shall meet the requirements out of ATEX IIC.
The related detailed requirements will be defined in /WP5 D5.4/.

5.8. Open topics

Some topics could not be finally closed for various reasons mainly due to missing input from various expert groups as well as postponed decisions in the project. These are:

- Interface coupler domain – CCU

For the time being, two different concepts for the control of the DAC exist: concept 1 has an integrated intelligence in the coupler itself which communicates with the CCU via the ECN, whereas concept 2 is directly controlled from the CCU with a discrete wired interface. Both concepts shall be developed, deployed, and tested in the field for a final decision.
The interface description will be updated by the DAC System Interface Clarification Group (part of WP5)

- Push buttons / signal lamps for manual operation of DAC

The detailed architecture of the panel with push buttons and signal lamps for the manual operation of the DAC and the interface to the coupler and/or the CCU must be developed at a later phase within FP5 because operational procedures as well as detailed train functions for decoupling are still pending.
The interface will be described in /WP5 D5.2/.

- Behaviour of a "dead" traction unit in a freight train

The operational requirements for a traction unit running as wagon in FDFT must be harmonized with the constraints to install the necessary components for this purpose what will be done at a later phase within FP5 or in other future projects.
The interface will be described in /WP5 D5.1/.

- Rear end signals requirements

The requirements for rear end signal (e.g. tail lights) in an automated environment must be defined before the system physical system architecture can be developed.
The interface will be described in /WP5 D5.2/.

- Reliability, availability, and maintainability

These topics are currently under discussion so that the necessary input for the development of the physical system architecture is still pending.
These topics will be handled by the FP5 RAM working group.

- Cybersecurity (HW aspects)

The topic of cybersecurity is currently under discussion so that the necessary input for the development of the physical system architecture is still pending.
This topic will be covered by the European Group "Cybersecurity".

- Interchangeability

Also, this topic is currently under discussion so that the necessary input for the development of the physical system architecture is still pending.
This topic will be handled by the FP5 group of operators, vehicle keepers and suppliers.

6. Conclusions

This document constitutes deliverable D3.2 “Physical reference system architecture FDFT” of ER JU Flagship Area 5 project FP5 TRANS4M-R. The project aims to boost innovation for the European rail freight sector, concretely by developing, validating, and demonstrating TRANS4M-R technical enablers.

The objective of this document is to provide the physical system architecture for rolling stock fitted with a DAC to enable the operation of full digital freight trains throughout Europe. The physical system architecture will serve – together with the functional reference system architecture described in D3.1 and the digital/data system architecture described in D3.3 - as foundation for authorisation of FDFTO and will define the basis for the development of the innovations for WP5-WP12.

While designing the architecture, open topics have been identified. The topics have to been solved in the future work within FP5 from other WP’s. Nevertheless, with this document the groundwork has been done for a common development of the FDFT. All other WPs can use this document as their foundation.

Based on the continuous development in TRANS4M-R, the feedback from the freight sector, new concepts, the system architecture will be developed further within FP5 and other projects to come.

7. References

Reference	*Publication date*	*Description*
WP2 D2.1	2023-06-30	WP2 D2.1: Preliminary Operational Procedures_v1.0.pdf
WP2 D2.3	2024-02-29	WP2 D2.3: Reference Freight System Architecture
WP3 D3.2	2024-04-30	WP3 D3.2: Physical reference system architecture FDFT
WP3 D3.3	2024-04-30	WP3 D3.3: Data reference system architecture FDFT
WP4 D4.1	2023-04-28	WP4 D4.1: Authorisation Strategy and Overall Safety Plan
WP4 D4.2	2023-11-15	WP4 D4.2: Risk assessment and harmonized safety architecture
WP5 D5.1	planned	D5.1: Functional Requirements Specification of Train Functions
WP5 D5.2	2023-12-20	D5.2: Technical Specifications of Wagon and Locomotive DAC up to Level 5
WP5 D5.4	planned	D5.4: Technical Specification of Wagon Power System and Communication System