RCA

Reference CCS Architecture

An initiative of the ERTMS users group and the EULYNX consortium

Concept: Track Occupancy

Concept Paper

Version 1 – Preliminary Issue

Document id: RCA.Doc.68

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Version history

Version	Date	Author	Version Notes
0.1	2022.02.17.	David Cuesta	Migration to RCA format. Resolved comments cleaned
0.2	2022.03.29	Petra Hubrig, Charlotte Gäbel, Lena Tillemann, Michael Krahl, Andreas Wenz, Saïd El-Fassi, David Cuesta, Muthukumar Kumar	Draft version of the content to be reviewed internally by EUG Localisation Working Group, RCA Advanced Protection System Cluster and RCA core team.
0.3	2022.04.01	Same as in Version 0.2	Working Version
0.4	2022.04.20	Same as in Version 0.2	Working Version
0.5	2022.06.24	David Cuesta	Ready for RCA internal review
0.6	2022.09.01		RCA comments
0.7	2022.09.09	Sebastian Ohrendorf-Weiss	Ready for core group review
0.8	2022.09.13	David Cuesta	Resolution of outstanding comments
1.0	2022.09.14	LWG	Initial Version

1 Introduction

1.1 Release Information

Basic document information:

RCA-Document Number: 68
Document Name: Track Occupancy Concept
Cenelec Phase: 1
Version: 1.0.0
RCA Baseline set: BL1
Approval date: 2022.09.14

1.2 Imprint

Publisher:

RCA (an initiative of the ERTMS Users Group and EULYNX Consortium)

Support and Feedback:
For feedback, or if you have trouble accessing the material, please contact rca@eulynx.eu.

1.3 Disclaimer

This issue is a preliminary version of this document. The content of this document reflects the current ongoing specification work of RCA. Requirements management and change management will be introduced in future iterations. The content may be unfinished, will likely contain errors and can be changed without prior notice.

1.4 Purpose of this document

This document is a concept paper written as part of the RCA's vision for a digitalized and automated railway operation. The document is written to provide a conceptual overview of how track occupancy is determined today using information from trackside and on-board systems and to illustrate the needs of the target system of RCA. The target scenario is presented as a combination of the information provided by the trackside assets and the localisation information coming from the train unit (see EUG.21E109). In addition, this document shall elaborate on potential localisation solution approaches to overcome existing challenges and shall provide first insights into the benefits of an approach based on accurate, highly available, safe localisation of movable objects, train integrity monitoring and trackside train detection systems. The combination of the information provided by the train unit and trackside can determine the actual position of the vehicle. This information will be used by the object aggregation and safety layer of the system to address the appropriate movement permissions in a safe and reliable way.

The document shall be treated as a concept and as an Input for future system design and specification work and not as a final standard reference tender specification document. This document does not intend to provide a technical solution to resolve or procure movements to the trackbound movable objects.

2 Introduction to the Track Occupancy Concept

Safe and accurate representation of track occupancies in the railway network is a major prerequisite to achieve both capacity improvements (e.g. by driving trains in braking distance) and safety improvements (e.g. by localising and considering also non-trackbound objects automatically).

The term *Track Occupancy* was in the past exclusively associated with status information reported by a Trackside *Train Detection (TTD) system*. An occupancy is used to indicate the usage of a track by none (e.g. in case of a TTD error), one or multiple unidentified objects. The drawback of this solution is that only trackbound movable objects [RCA.Doc.67] causing an occupancy themselves (e.g. railway vehicles such as trains and wagons) can be detected and that considering the determined occupancy for vehicle movements limits track capacity as it spans one or multiple complete block sections even if the real object extent is much smaller.

With improvement of on-board localisation and trackside train detection technologies it becomes possible to use additional information such as vehicle-derived train position reports (including train integrity) to get a more precise view about the real object extent. Furthermore, the development of Movable Objects equipped with localisation systems makes it possible to localise more, even non-trackbound movable objects, such as construction equipment (e.g. two-way vehicle) and railway staff (e.g. track worker).

Having this in mind, the meaning of the term *Track Occupancy* has to be enlarged. In scope of RCA it shall therefore be understood **as a representation of an area of the track (with possible zero extent) that is either occupied by a railway vehicle, construction equipment or by authorised railway staff or for which cannot be excluded that it is occupied by such an object.**

Note: occupations produced by external actors to RCA such as animals, people, vehicles, should be detected by other systems e.g. trackside sensors or onboard perception mechanisms.

A Track Occupancy is defined by at least one position (i.e. a Track Edge Point in the topology), an extent and an optional safety margin.

2.1 Scope

The document is a concept about determination and extension of train unit using information from trackside and on-board systems and providing the same as an input for other systems including but not limited to the Object Aggregator (OA) and Safety Logic (SL).

Note: In this version of the document, only the track occupancy by Trackbound Movable Objects has been addressed. Future iterations of the document will address the determination and representation of track occupancies by Non Trackbound Movable Objects such as construction vehicles and authorised staff.

The functional description provided by this document inside the RCA framework, describes the elements which contribute to define the occupancy of the tracks and that will be used to safeguard the safety and integrity of the railway operation. Therefore, functional needs for track occupancy are defined and allocated to existing and future subsystems. It is not the purpose of this document to define these processes that will deliver a movement permission to resolved Movable Objects (rMOB). Figure 1 depicts the area in which this document is focused with a red rectangle.

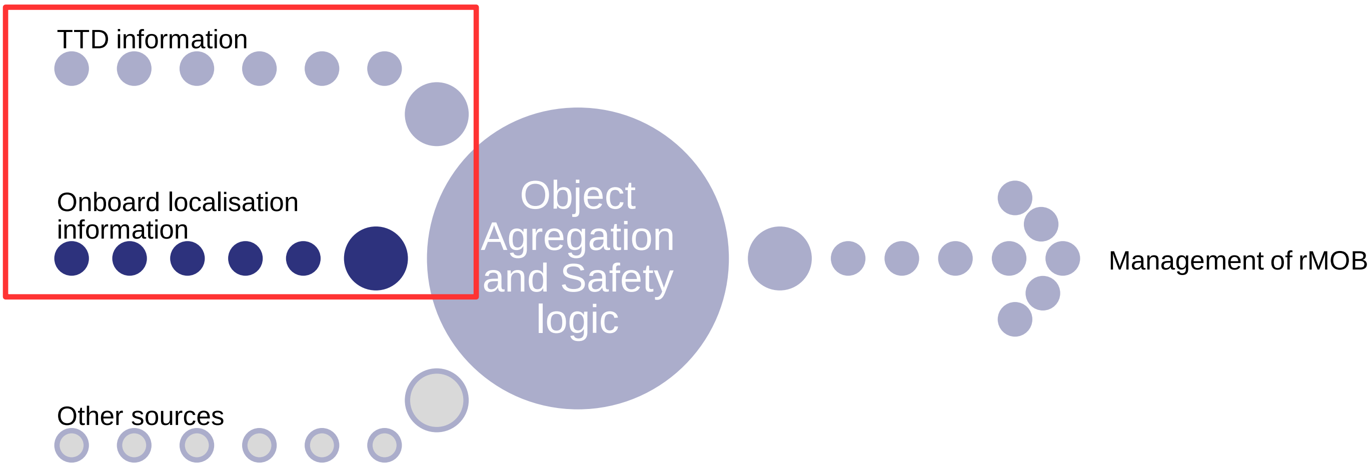


Figure 1: Inputs for the determination of rMOB

In terms of the functional architecture referenced to /RCA.Doc40/ the highlighted parts are the ones addressed by this document

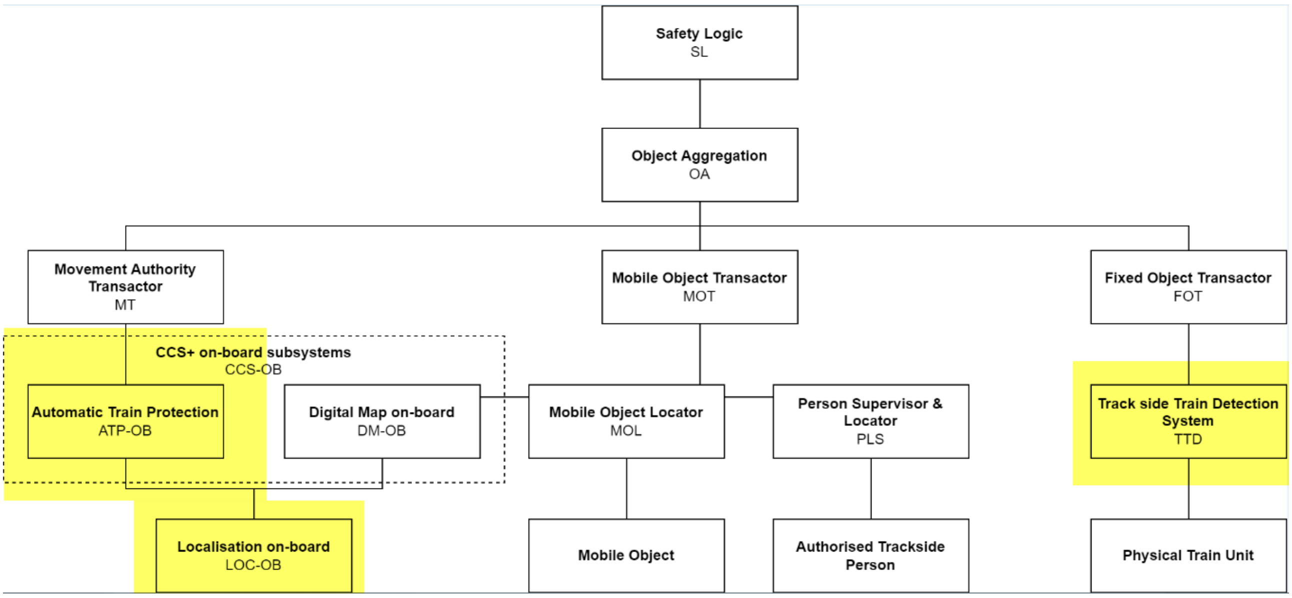


Figure 2: Involved functional elements regarding RCA architecture

As shown in Figure 2, the information coming from the TTD and the CCS-OB is combined at the aggregation level to determine the track occupancy.

2.2 Use of this document

This document can be used

- for informing consuming working groups and document authors about the operational and system context description of the track occupancy concept
- for operational and system context description of the track occupancy concept.
- for getting informed by needs of the track occupancy function.
- As a possible solution for radio based ETCS.
- for implementation strategy for the track occupancy function.

2.3 Target group

This document is intended to be used by the RCA and OCORA members. It is meant to be the basic information on the track occupancy concept for the System Pillar.

2.4 Related documents

Document	Remarks	Version number
RCA – APS Concept		
RCA Architecture Poster	RCA.Doc.40	0.4(0.A)
RCA plateau migration approach	RCA.Doc.28	1.2
CR1368	Economic Justification	1,0
EUG-LWG Remit		2.0
EUG Localisation Concept Architecture	EUG.21E109	1.0
RCA mains concepts and goals		
OCORA-TWS01-100 | Localisation On-Board (LOC-OB) – Introduction	OCORA main concepts and goals	
OCORA-TWS01-101 | Localisation On-Board (LOC-OB) – Requirements	OCORA main concepts and goals	
LWG Document Structure Proposal	LWG DSP	1,0
Joint Working Group «Concept Paper» (Aug, Map)	CP	1.0
Vehicle Locator Concept Architecture	VLCA	1,0
RCA Glossary		
Digital Map System Definition	RCA Doc 59	1.0
MAP Object Catalogue	RCA Doc 69	1.0
Subset-023	ERTMS/ETCS Glossary of Terms and Abbreviations; UNISIG Subset-023	3.6.0
Subset-026	ERTMS/ETCS System Requirements Specification; UNISIG Subset-026	3.6.0
Subset-113	ETCS Hazard Log	1.3.0
RCA System definition	RCA.Doc.35	

Table 1: Related Documents

2.5 Terms and abbreviations

2.5.1 Terms

Hereunder some of the terms used across the document will be explained. The reader is invited to check /RCA:Doc.14/ for other terms.

Extent:

This term has a different meaning depending on the concrete usage. When used in relation with a real-world object physically present in the railway track, it refers to its physical extent, i.e. the length of the object. Trackside receives localisation information for this real-world object via different channels, i.e. submitted by the real-world object itself or via Trackside Train Detection (TTD) systems and it derives a corresponding occupancy extent, i.e. a trackside view about the object extent If this localisation information already contains location inaccuracy (e.g. train confidence interval or safe train length in today's ETCS position reports), the trackside view about an object's extent and therefore its representation in the operating state is usually larger than the real extent of the physical object itself. Finally, safety margins may also be added optionally to the object extent.

Linking

A functionality to protect against missing data from BALISE GROUPS by announcing them in advance through LINKING INFORMATION and by checking whether they have been read within a certain EXPECTATION WINDOW. Refer to /Subset-023/.

Linking Information

Data defining the distance between groups of balises, their identity and orientation, and the action to be taken if an announced balise group is not detected within given limits (EXPECTATION WINDOW). Refer to /Subset-023/.

Operational scenario:

A specific situation in which a train, vehicle or object is used to perform an operational task, resulting in a section of track being occupied.

Regular operational setting

An operational setting that is intended by the operator and is needed for the proper functioning of the railway system.

Degraded operational setting:

An operational setting that is not intended by the operator, where one or more components of the railway system have failed, and operational goals cannot be achieved as expected.

Train Integrity:

The level of belief in the train being complete and not having left coaches or wagons behind. Refer to /Subset-023/.

Track Occupancy:

A Track Occupancy is a representation of an area of the track (with possible zero extent) that is either occupied by a railway vehicle, construction equipment or by authorised railway staff or for which cannot be excluded that it is occupied by such an object.

A Track Occupancy is defined by at least one position (i.e. a Track Edge Point in the topology), an extent and an optional safety margin.

Track Vacancy Proving Section (TVPS):

According to EULYNX Eu.Doc.9 a Track Vacancy Proving Section (TVPS) is a portion of track which the Interlocking system can recognise by means of a track vacancy proving system. In scope of RCA the TVPS state is no more evaluated by an Interlocking. A Track Vacancy Proving Section

(TVPS) will be understood in scope of RCA as a portion of the track which the trackside system can recognise by means of a Trackside Train Detection (TTD) system.

2.5.2 Abbreviation

Abbreviation	Description
APS	Advanced Protection System
CCS	Command Control & Signalling
ELF	Enhanced Localisation Function
ERTMS	European Rail Traffic Management System
estFE	Estimated front end
maxSFE	Maximum safe front end
minSFE	Minimum safe front end
minSRE	Minimum safe rear end
ETCS	European Train Control System
IL	Interlocking
LOC-OB	Localisation Onboard
MOB	Movable Object
MOL	Mobile Object Locator
MCI	Mission Confidence Interval: Maximum acceptable value of the difference between maxSFE / min SFE and the estFE
PSL	Persons Supervisor & Locator
RCA	Reference CCS Architecture
rMOB	Resolved Movable Object
RFID	Radio Frequency Identification
TEP	Track Edge Point
TIMS	Train Integrity Monitoring System
TPR	Train Position Report
TTD	Trackside Train Detection
TVPS	Track Vacancy Protection Section
TSI	Technical Specification for Interoperability

Table 2: List of Abbreviations

2.6 Structure of this document

In chapter 3 “Track Occupancy Determination” different possibilities to determine the track occupancy are proposed as well as solutions and challenges for the future Track Occupancy Function described in this document.

In chapter 4 “Target Picture“ long-term objectives and key aspects which are needed to fulfil the needs of the railway system of the future are described.

Chapter 5 “Functional needs towards Localisation” shows the information which shall be provided for determining track occupancy.

In chapter 6 “Operational ”,Setting different operational situations with some attributes, described on a high-level are presented. This description does not intend to describe operational behaviour but aims to:

- derive the needs of the Track Occupancy Function
- show that all operational settings are covered by the Track Occupancy Function in a safe, accurate and highly available way
- formulate migration requirements, for a second version of the Track Occupancy concept

In chapter 7 “Track Occupancy”, a high-level logical architecture is presented. Therefore the different localisation subsystems, including support information are described.

3 Track Occupancy Determination

3.1 General introduction

This chapter takes a closer look at limitations when determining track occupancies based on today's technologies. Here, the focus lies on occupancy information provided by Train Detection Systems and onboard-localisation information (including train integrity and safe train length) provided and processed in scope of radio-based ETCS. How train integrity is provided, is out of the scope of this document. ETCS Level 1 and national train control systems are not considered.

3.2 Localisation of trackbound railway vehicles in today's signalling systems

3.2.1 Information provided by Trackside Train Detection System

3.2.2 Description

Nowadays, a Trackside Train Detection (TTD) system belongs to an electronic interlocking (IL). It contributes significantly to the safety of the signalling system by reporting occupancy states of block sections in the railway track. A TTD therefore provides the prerequisite for train movement protection based on geometric spacing as under normal operational conditions only one train is allowed to enter a dedicated block. A TTD can be realised using different technologies as for example axle counters or track circuits.

3.2.3 Limitations

3.2.3.1 Reduced number of objects detected

One drawback of deriving the track occupancy solely from TTD information is that only a limited number of trackbound railway vehicles can be detected. These are for example items of rolling stock such as a wagons or engines. They are able to trigger an occupancy that will be recognised by the TTD. On the other hand, occupancies caused by non-trackbound railway objects, such as construction vehicles or railway staff, are not detected with this technology, as these objects do not fulfil the trigger conditions, e.g. due to accessing the track only temporarily and/or by via arbitrary access points.

3.2.3.2 Oversized Occupancy Extent

When using a TTD, the railway track is physically divided into sub-sections, so called block sections or *Track Vacancy Proving Sections* (TVPS). A track occupancy determined based on TTD status information is usually larger than the real extent of the corresponding railway vehicle as it spans one or multiple complete TVPSs. The exact position of the railway vehicle inside a TVPS is not known. Having in mind that under normal operational conditions only one train is allowed to enter a block section, the size of these sections has a significant impact on track capacity. The next picture (Figure 3) illustrates that a subsequent train (train B) can only follow a preceding train (train A) after the preceding train has left the block section (TVPS 2) and it is reported to be vacant.

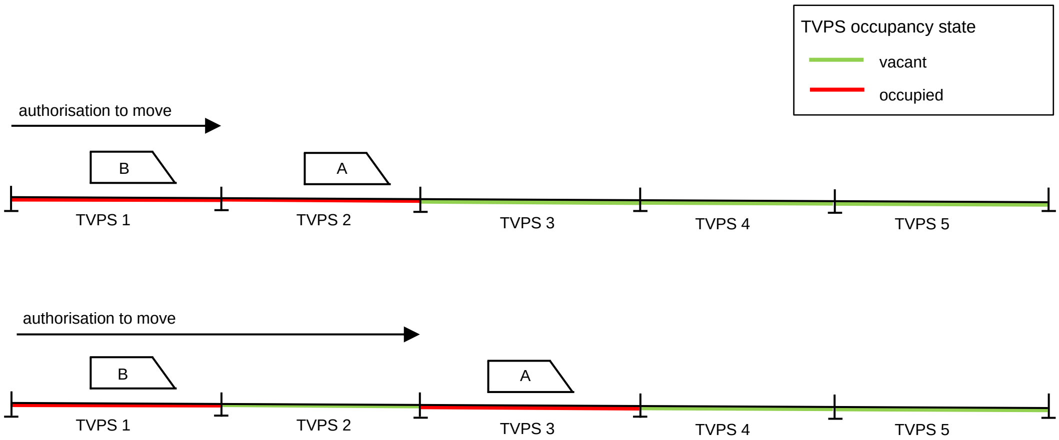


Figure 3: Track usage with fixed blocks

3.2.3.3 Undetected overhang

Using a TTD the following situation can occur: a railway vehicle (train/loco or single wagon) can occupy a TVPS based on the position of its axles but its real extent (the additional part of the railway vehicle from axle position to front/rear) can extend into a vacant TVPS (at least as vacant reported by TTD based on the axles of the railway vehicle.) The following picture (Figure 4) illustrates this situation:

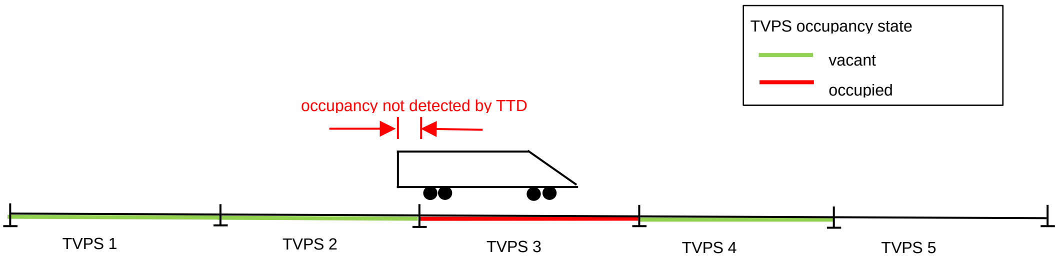


Figure 4: Undetected overhang

Thus there might be a safety issue because the vacant reported TVPS is not completely vacant in reality, if only two states vacant and occupied are defined. Today this problem is solved by exploitation rules and a third state, e.g. TVPS partially occupied. In areas of special interest this issue is solved by design or operational measures (e.g. specific placement of axle counters in the area of points/fouling points).

3.2.4 Information provided by ETCS train

3.2.4.1 Description

Trains equipped with the *European Train Control System* (ETCS) are capable of sending position information to trackside by means of ETCS Position Report (Packet Number 0 and Packet Number 1). Sending the Position Report to trackside is triggered either by specific events (see “Active Function Table” in /Subset-026/ chapter 4) or by a timer. Train detection based on on-board localisation information is called *On-board Train Detection (OTD)*.

The ETCS Position Report contains several data concerning:

- ➔ Reference location (LRBG)
- ➔ Confidence interval of the train

➔ Safe train length if train integrity is available
➔ Further train data (e.g. speed, ETCS Mode, ETCS Level).

The following parameters contained in position report packets influence the view of the trackside system on the track occupancy (see /Subset-026/ chapter 7 “Packet Number 0: Position Report” and “Packet Number 1: Position Report based on two balise groups”):

Parameter	Description	Remark
NID_LRBG (NID_PRVLRBG)	identity of L*ast Relevant Balise Group* (LRBG) (or previous LRBG, respectively)	The balise group identity enables trackside to locate the position of the train in the topology/map. It provides track-selective information, e.g. if the train reports a new LRBG after passing a facing pair of points, trackside can safely conclude on which points leg the train is located.
D_LRBG	distance between the LRBG and the estimated front end of the train (the side of the active cab)	see explanation below in Figure 5
L_DOUBTOVER	over-reading amount plus accuracy (Q_LOCACC) of the LRBG	see explanation below in Figure 5
L_DOUBTUNDER	under-reading amount plus accuracy (Q_LOCACC) of the LRBG	see explanation below in Figure 5
Q_LENGTH	qualifier, identifying the train integrity information available	The safe train length is only contained in the packet if this qualifier indicates that integrity information is available (i.e. confirmed by driver or integrity monitoring device).
L_TRAININT	safe train length	see explanation below the table
Q_DIRTRAIN	direction of train movement in relation to the LRBG orientation	The direction of train movement may have an impact on track occupancy determination if different rules are applied to determine the safe extent at the front and at the rear of the train. Example: In case of considering a rollback distance this distance needs to be applied to the other end (former front of train) when changing the train movement direction.

Table 3: Parameters contained in position report packets relevant for track occupancy determination

Figure 5 (source figure 13c of /Subset-026/ chapter 3) depicts the relation between LRBG and the different train front end positions:

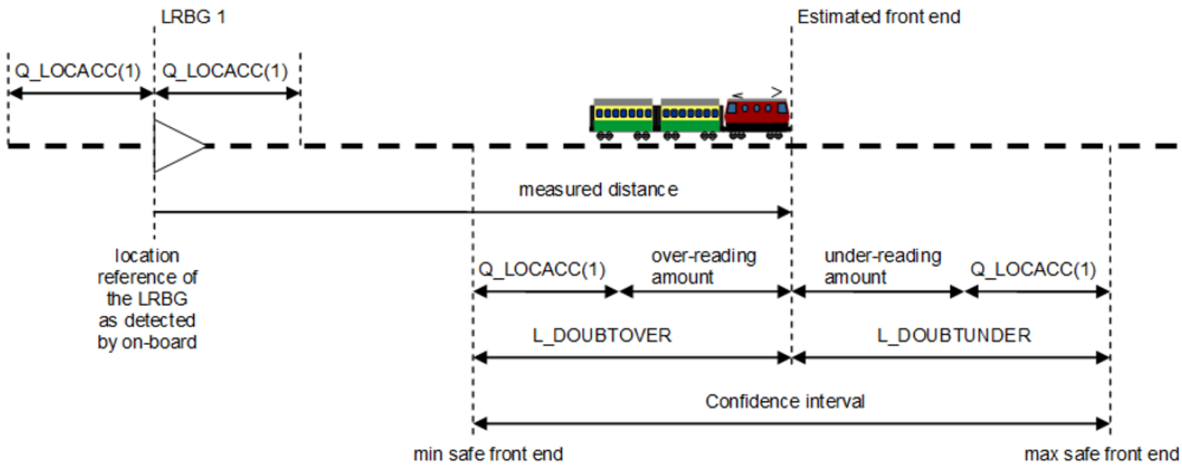


Figure 5 : Train positions determined on balise passage

According to /Subset-026/ chapter 3 "Train Position Confidence Interval and Relocation", the train positions are determined the following way:

- ➔ The *estimated front end* (estFE) is determined based on the distance measured to the LRBG (D_LRBG).
- ➔ The *maximum safe front end* (maxSFE) differs from the estFE by the under-reading amount in the distance measured from the LRBG plus the location accuracy of the LRBG. L_DOUBTUNDER.
- ➔ The *minimum safe front end* (minSFE) differs from the estFE by the over-reading amount in the distance measured from the LRBG plus the location accuracy of the LRBG. L_DOUBTOVER.
- ➔ The rear end positions are determined the same way. However, the minimum safe rear end position (minSRE) is only safe if derived from a position report indicating train integrity.

The distance between min and max safe front end is called train position confidence interval. According to /Subset-023/ it defines the distance interval within which the ETCS on-board assumes the actual train position (i.e. estimated front end), is with a defined probability. It comprises the odometer over-reading and under-reading amounts, plus twice the location accuracy of the reference balise group.

The *safe train length* is only contained in the ETCS position report if train integrity information is available and on-board position information is valid. The *safe train length* represents the distance between the min safe rear end position at the time the train was last known to be integer and the estimated front end position of the train at the time when the train integrity information is sent to trackside (see Figure 6, source: /Subset-026/ chapter 3 figure 15):

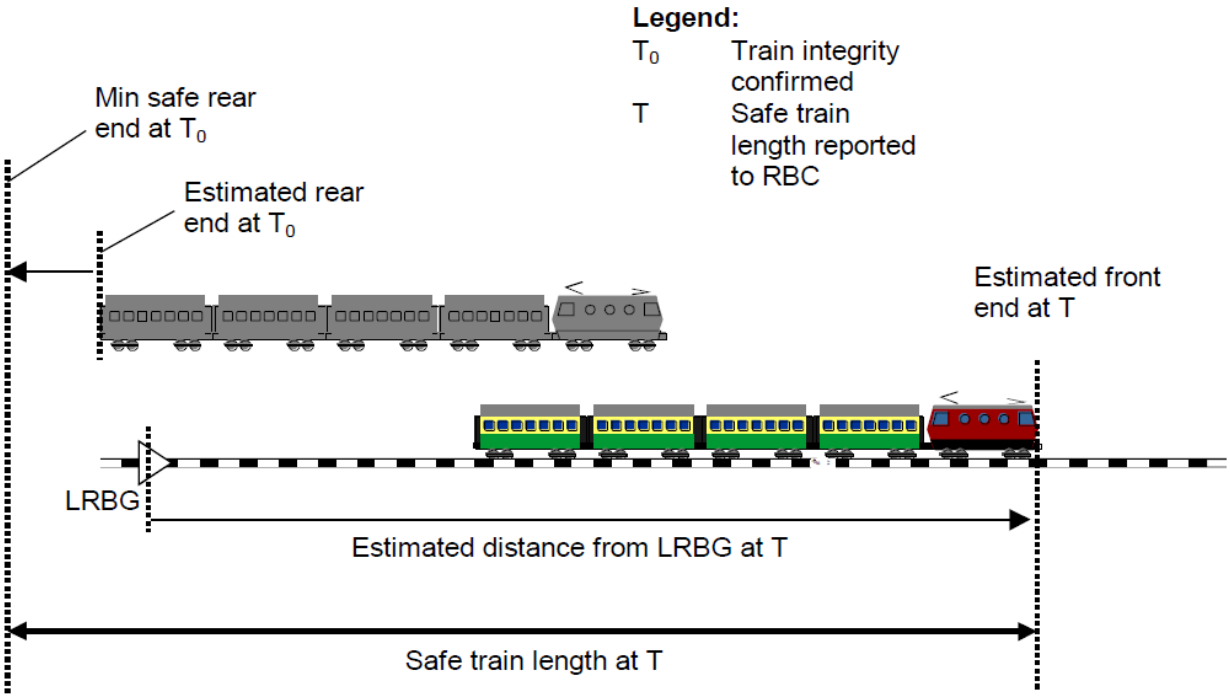


Figure 6: Determination of safe train length in case of train integrity

If the track occupancy is exclusively determined based on position report information, it would cover the area between maxSFE and the rear end derived from the safe train length, i.e. minSRE at the time of integrity confirmation. Nevertheless, further limitations arise when passing points. Please refer to chapter 3.2.4.2.5 for more detailed information.

3.2.4.2 Limitations

3.2.4.2.1 No continuous provisioning of position reports. Communication unavailability.

According to the Active Function Table contained in /Subset-026/ chapter 4, the frequent submission of ETCS position reports is currently limited to dedicated ETCS modes. In modes like Shunting, Passive Shunting and No Power, the train does not regularly inform trackside about its current position. Determining the track occupancy exclusively based on ETCS position reports is not possible in these situations. This problem is already addressed in one of the game changers change requests (refer to CR1350 – always connected, always reporting).

3.2.4.2.2 Position report frequency

An ETCS position report informs trackside about the train front end and in case of train integrity, the safe train length from which the rear end position at a certain point in time can be derived. It provides a snapshot view to trackside. The position report frequency has a direct impact on track capacity, especially when driving in close distance. This can be attributed to the fact that a subsequent train can only use a part of the track formerly occupied by a preceding train if trackside is aware of the fact that this part is already vacant.

As depicted in Figure 7 , the trackside view of the train A extent is updated on reception of a position report. A high position report frequency ensures that trackside has a more accurate view about the current train position. It enables trackside to detect in time that a part of the track has already become vacant again and can therefore be used for subsequent train movements (train B).

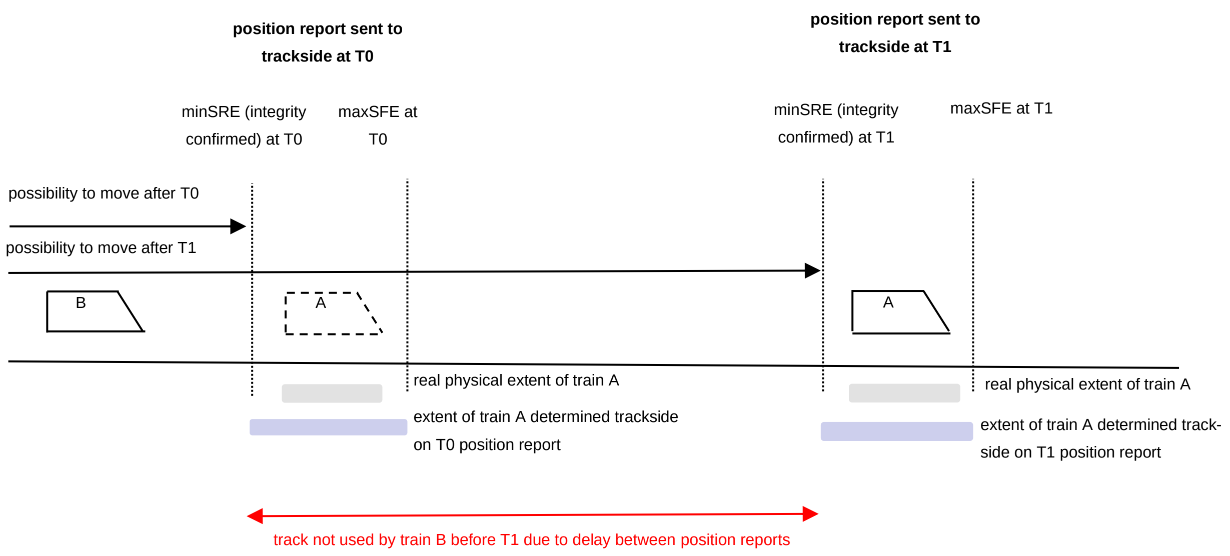


Figure 7: Impact of position report frequency

3.2.4.2.3 Position report latency

Another aspect that impacts the trackside view regarding train position and extent is the latency of the transmission system, i.e. the delay between the position report submission on-board (T1) and its reception on trackside (T2). The Figure 8 illustrates that the trackside view is already outdated at the time when the position report is finally received (T2) because the train moved on during the message submission (refer to minSRE/maxSFE at T2 – both not yet reported to trackside). The lower the latency, the more accurate the trackside view of the train extent and the earlier a subsequent train (B) can follow a preceding train (A).

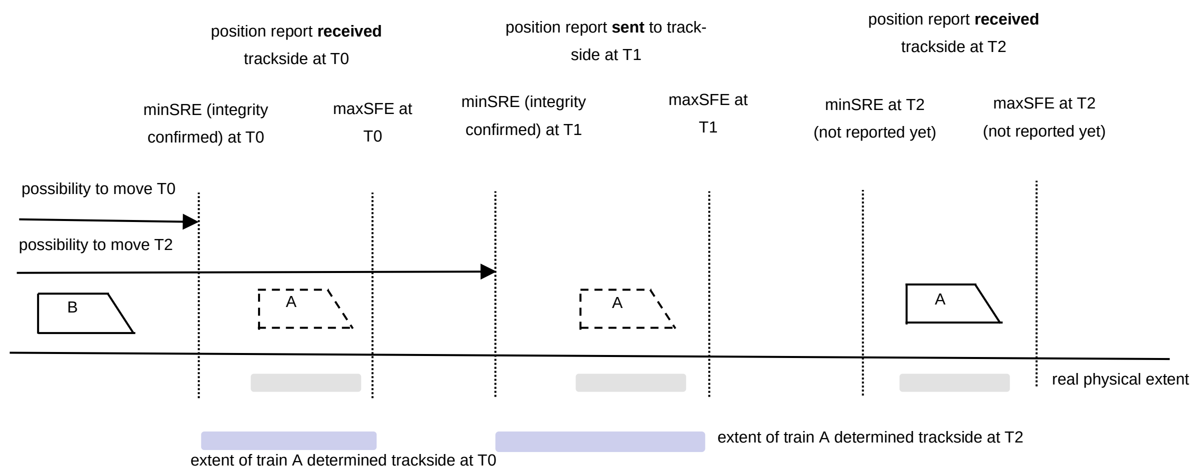


Figure 8: Impact of the position report latency

3.2.4.2.4 Integrity report frequency

As explained in chapter 3.2.4.1 the safe train length defines the distance between the min safe rear end position at the time the train was last known to be integer and the estimated front-end position of the train at the time when the train integrity information is sent to trackside. Consequently, the frequency of on-board integrity determination has a direct impact on track capacity. This is illustrated in the picture below:

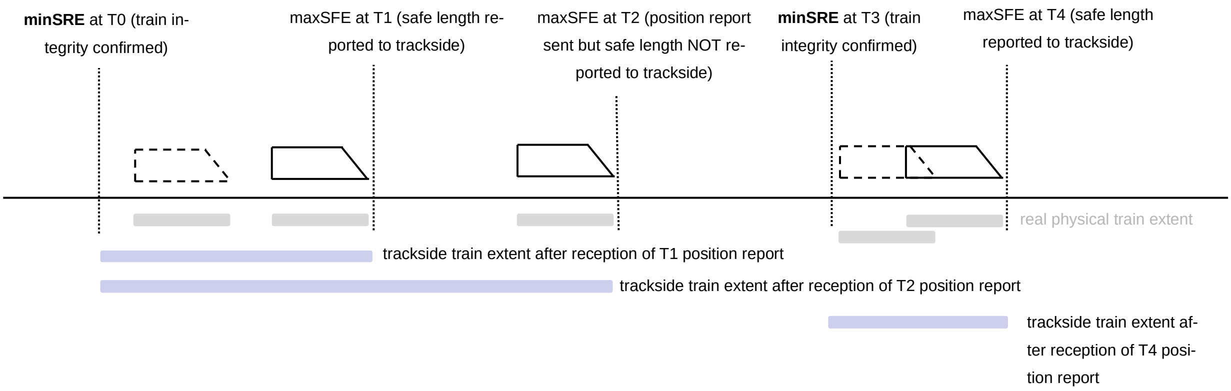


Figure 9: Impact of the integrity report frequency

Figure 9 illustrates that the minSRE is determined on-board at T0 and at T3 whereas ETCS position reports are sent to trackside more often (e.g. at T1, T2 and T4).)., at these instants, train position report contains train integrity status unknown. As a consequence, trackside may have an outdated view about the train's minSRE position. As depicted by large purple bars compared to the real physical extent of the train depicted in grey, see for example T2 where the maxSFE end information is updated in scope of position report submission but the minSRE remains at the T0 position because this was the last time that train integrity was determined on-board. Hence, the rear end extent of the track occupancy is only updated once a train position report with train integrity status "confirmed" is received.

3.2.4.2.5 Confidence interval and location inaccuracy

As described in chapter 3.2.4.1, the value of the Confidence Interval (CI) and thus the location inaccuracy (large confidence interval = large location inaccuracy) depends mainly on

- ➔ Travelled distance from LRBG
- ➔ Location accuracy of the LRBG.

Figure 10 shows that under normal operational conditions, considering an accumulating error that increases with the travelled distance, the confidence interval is reset at each balise which is marked as linked and contained in the Linking Information (Packet Number 5) and thus represents a LRBG.

From that, the following main issues influencing the CI value can be derived:

- ➔ Using linking functionality/availability of Linking Information: without linking functionality and/or Linking Information the CI will not be reset (or reset "later") Thus the CI increases.
- ➔ Distance between LRBG: a large distance between two LRBG (and thus a reduced number of balises) leads to an increased CI.
- ➔ Location accuracy of the balises: a high location inaccuracy of the balises leads to an increased CI.
- ➔ Non-linear, significant increase of confidence interval due to sensor misbehaviour

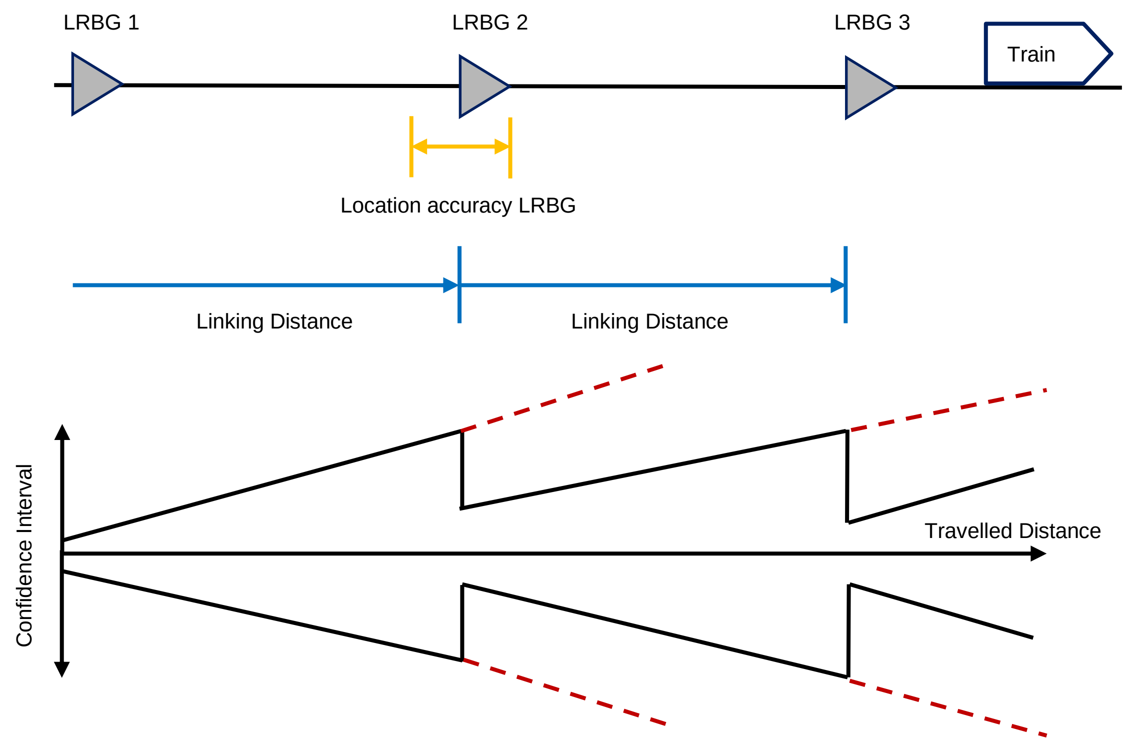


Figure 10: Reset of Confidence interval on LRBG change

Due to the existing CI (as described above) there is a certain location inaccuracy. This leads also to localisation issues in some specific infrastructure and operational situations. One example is the trackside front/rear end determination close to a point (see Figure 11). Based exclusively on localisation information such as an ETCS Position Report, trackside cannot always unambiguously determine which point leg is occupied by the train. For safety reasons, the point position cannot always be evaluated, especially not if the train does not occupy the point. The bigger the confidence interval (i.e. the bigger the deviation between real and maximum outer train position), the more complex is the determination of the occupancy extent on trackside. Depending on the concrete operational situation, additional information such as history (Where does the vehicle come from?), reserved track path (Where is the vehicle expected to go?), point positions and/or TVPS states have then to be considered in order to derive the correct track occupancy.

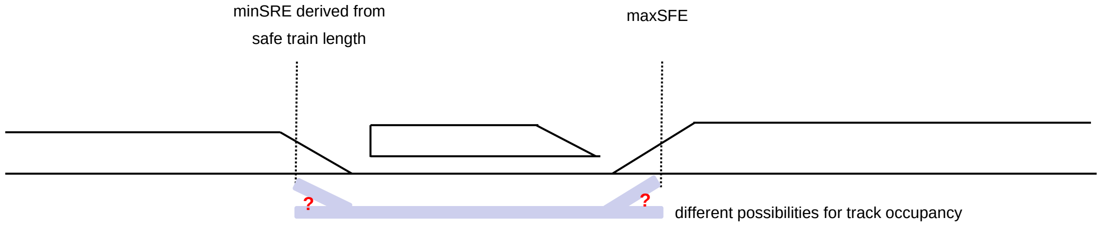


Figure 11: Determination of track occupancy in case of points

It must be noted that the confidence interval is purely determined by the on-board and it's not in the scope of this document to analyse how it can be improved, neither technologically nor by means of engineering measures.

3.2.4.2.6 Starting up with invalid or unknown or valid but not trustworthy train position

During Start of Mission (SoM) an ETCS OBU is going to report a valid, invalid or unknown train position (refer to /Subset-026/ chapter "Procedure Start of mission"). This refers to the validity status of the stored LRBG and depends on both current operational situation and technical train equipment:

- ➔ The ETCS OBU reports a **valid position** if a valid LRBG is stored on-board and it can be safely excluded that the OBU has performed an unsupervised train movement, e.g.
  - o The OBU starts up from a mode in which the train position is determined in relation to the LRBG (refer to /Subset-026/ chapter 4 "Active Function Table"). Examples: SoM from Sleeping or Non Leading mode after train splitting or turnaround movement or SoM after Shunting or Passive Shunting.
  - o The OBU starts up from a mode in which the train position is not determined in relation to the LRBG but a cold movement detector installed on-board can exclude that the position has not changed compared to the stored position (or reveal a movement otherwise). Example: SoM from No Power mode, e.g. after being parked in a depot or stabling siding.
  - o After SoM with invalid position that was confirmed by trackside
- ➔ The ETCS OBU reports an **invalid position** if an LRBG is stored on-board but it cannot be safely excluded that the OBU has performed an unsupervised train movement. Example: the OBU starts up from ETCS mode No Power (e.g. after being stabled) and there is no cold movement detector installed on-board. If trackside is able to verify the train position, it sends a corresponding message to the OBU (see message 43). If trackside is not able to verify the position this is also indicated (see message 41). In case of missing confirmation, the OBU deletes the stored position information and reports with immediate effect an unknown position until passing a new balise group.
- ➔ The ETCS OBU reports an **unknown position** if no LRBG is stored on-board, e.g. in case of initial commissioning or after having performed SoM with invalid position that wasn't confirmed by trackside.

Chapter 3.2.4.1 outlines that the LRBG is used to determine the train front end position on-board and to locate the train trackside in the topology/map. It provides the basis for determination of the track occupancy. If the LRBG is unknown or invalid (without trackside confirmation) the train cannot be located in the topology/map and a track occupancy cannot be determined. Furthermore, an OBU cannot report train integrity in these situations even if integrity is confirmed on-board as the safe train length cannot be calculated based on missing train positions[1].

If a train reports a valid position during SoM, trackside cannot simply trust it. This can be attributed to the fact the train can be located on another points leg than indicated by the reported LRBG (please refer to UNISIG hazard ETCS-H0003 described in /Subset-113/). Nowadays, this problem is often solved by defining so called Trusted Areas (TA) for track areas in which trains usually start-up. Trackside can classify a balise group that is reported as LRBG and located inside a TA as trustworthy, but safety then needs to be ensured either by

[1] Please refer to the solution proposal of CR940 that will be incorporated into UNISIG Subset-026 with TSI 2022. The following explanation will be added as paragraph 3.6.5.2.7:

> Note: As long as no Train Data "safe train length" is available or the train position is not valid or not referred to an LRBG, the ERTMS/ETCS on-board equipment cannot report that the train integrity is confirmed, regardless of the train integrity information received from an external device. Justification: in order to calculate the confirmed train length when reporting a train integrity confirmation, the train position must be valid and referred to an LRBG and Train Data "safe train length" must be available at the time of the train integrity confirmation.

additional technical or by operational measures. The former can be achieved e.g. by balise engineering rules such as placing additional balise groups around points. The latter can be achieved by defining operational rules that prevent train movements leading to the hazardous situations. Depending on concrete topological conditions and interfacing systems, trackside implementation is sometimes also able to conclude itself that a train cannot be located on a parallel points leg.

3.2.4.3 Combination of information received from different sources

3.2.4.3.1 General introduction and problem description

As described in the chapters above today trackside mainly receives localisation information from two different sources:

- ➔ TVPS status submitted by TTD system
- ➔ Position reports sent by ETCS-equipped Train Units including train integrity related information (OTD).

In order to derive a more accurate picture of the real physical track occupancy, it seems to be reasonable to combine this information. Furthermore, localisation technologies are evolving and therefore additional information can be provided to trackside (e.g. rear end position also reported via another channel). Nevertheless, when combining information of different sources, additional aspects have to be considered, especially correlation and timing issues. Timing issues should become controllable due to the use of a shared time service for RCA all subsystems. See RCA.Doc.78, section 2.1.2.

Correlation issues arise if information submitted via different sources cannot uniquely be assigned to the same originator. Example: An ETCS-equipped Train Unit A is moving , the TVPS occupancy is reported via the TTD. Additionally, the train sends ETCS position reports to trackside. Trackside cannot safely conclude from the TTD status report that the corresponding occupancy has been caused by ETCS train A as this report neither contains information regarding the originator nor regarding the occupancy direction (e.g. corresponding / opposite to train running direction). Trackside needs to consider additional information (such as state of neighbouring TVPS, path reserved for train movement, position of other trains, etc.) to safely conclude that the reported TVPS occupancy is caused by the moving ETCS train A and not by any other railway vehicle.

Timing issues arise if information from different sources reaches trackside at different points in time e.g due to different transmission delays. The problem arising from that fact is how to correlate the different messages, e.g. to decide which information is up-to-date and which one is already outdated. Furthermore, trackside needs to evaluate if the information reported from different sources fits together in the sense of being plausible and having the same safe result concerning the position and/or extent of the train. One specific example: there are three different localisation information such as train front end position sent to trackside by means of ETCS position report packet, train rear end position sent to trackside via another channel (see 7.3.3) and an occupancy status reported by the TTD. When combining these three information the described issue can occur. If there is a drift between the time bases of on-board and trackside system , the effect of the timing issue could be increased. Suitable measures have to be defined to cope with this problem (e.g. computing the offset).

3.2.4.3.2 Examples for aggregation of TTD status information and ETCS position reports

This section describes common situations in which trackside determines the track occupancy based on different localisation information. Please note that safety margins are not considered yet for simplification reasons. Chapter 3.2.4.3.3 is going to deal with this topic.

In the first example (Figure 12), the ETCS train reports train integrity and the occupancy extent derived from the ETCS position report is bigger than the extent derived from the TTD status information (TVPS2, TVPS3):

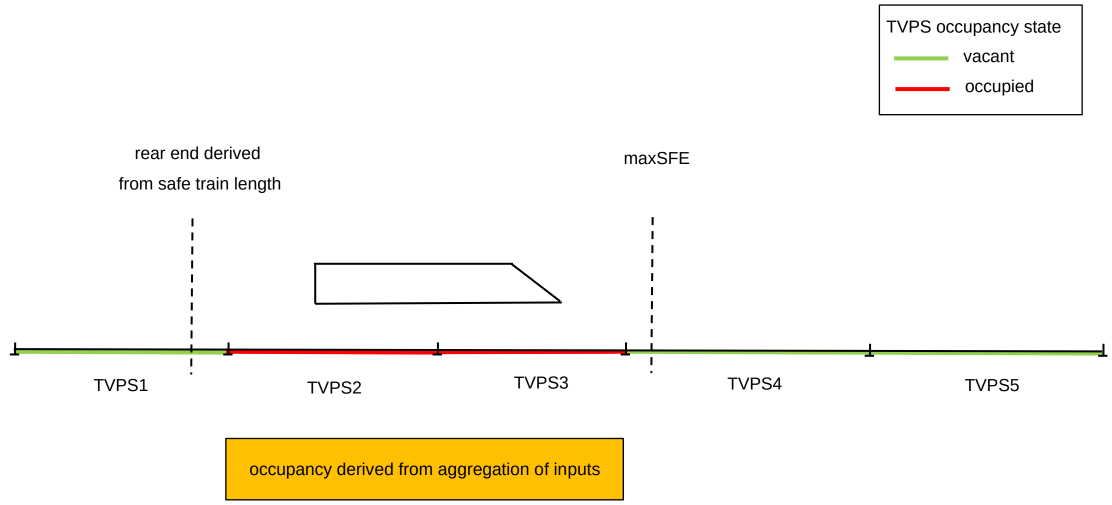


Figure 12: Reduced track occupancy based on TTD information

The resulting track occupancy extent is derived from the TTD information and is smaller than the extent indicated in the Position Report because both maxSFE and the rear end position calculated from the safe train length are located in a vacant TVPS (TVPS1 and TVPS4). Consequently, trackside can safely conclude that the train is not located within these track sections.

In the second example (Figure 13), the ETCS train reports also integrity and the occupancy extent derived from the ETCS position report is bigger than the extent derived from the TTD status information (TVPS2, TVPS3) but the neighbouring TVPSs are occupied by other trains:

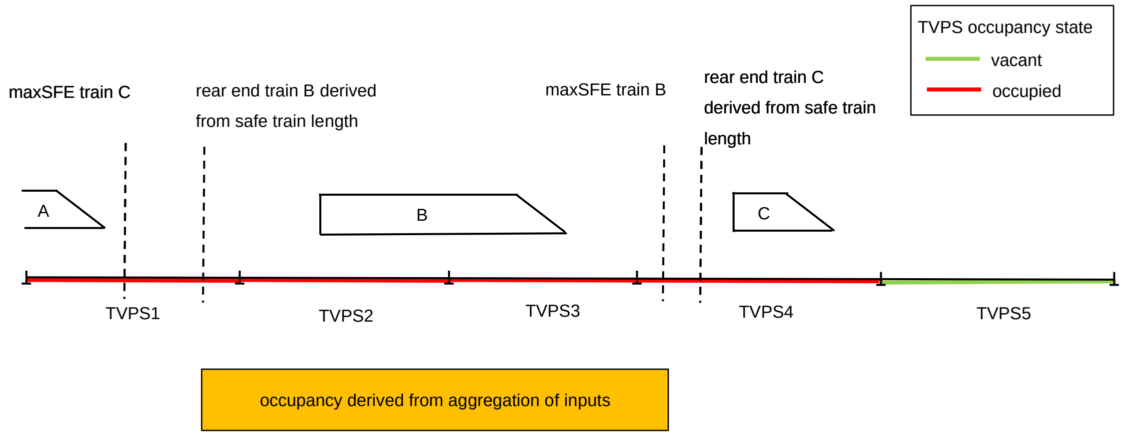
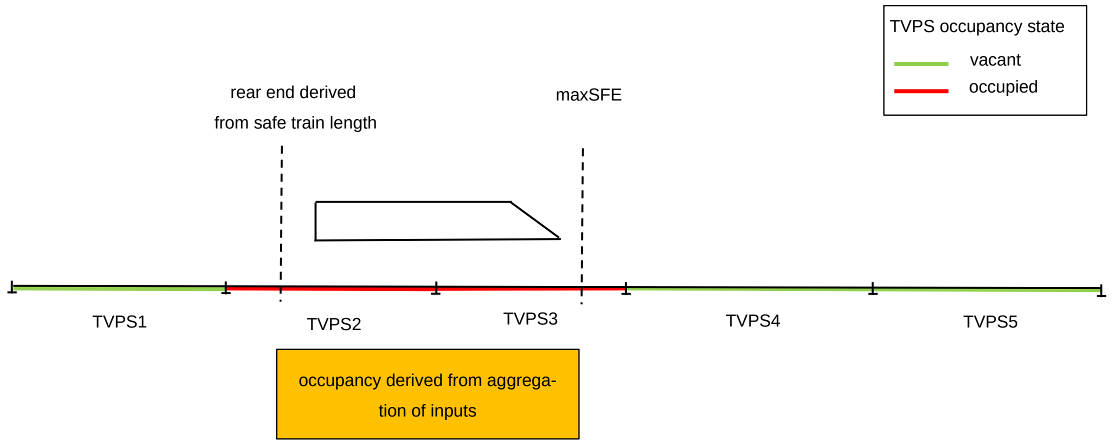


Figure 13: Confidence interval impacts track occupancy

Figure 13 illustrates that trackside cannot safely conclude that train B is neither located in TVPS1 nor in TVPS4 and therefore the resulting track occupancy extent cannot be reduced. Here it becomes obvious that the size of the Confidence Interval has a significant impact on determination of Track Occupancy and thus on track capacity. The same statement applies to situations in which the track occupancy is determined exclusively based on on-board localisation technologies, e.g. if TTD is installed along the track but the localisation information received from the train provides a more accurate picture about train position and extent (see Figure 14):



Please note: In this situation the track occupancy can be shortened to the positions derived from the ETCS position report if trackside can safely exclude that any other railway vehicle is additionally located inside the occupied TVPSs (TVPS2, TVPS3). If this isn't the case additional safety measure have to be applied.

Figure 14: Track occupancy derived from on-board localisation

3.2.4.3.3 Localisation inaccuracy and safety margins

The trackside view on Track Occupancy includes always a certain location inaccuracy. This fact is explained in chapters above by the described limitations of localisation information by TTD and ETCS Train Position Report. It was shown (refer to chapter 3.2.4.2.5), that an increase in localisation inaccuracy leads to increased complexity when determining Track Occupancy (see example with point in this chapter).

In addition to that, safety margins could become applicable and then have to be considered when combining localisation information. The necessity and also concrete values (or value ranges) have to be clarified in scope of a safety analysis. But it has to be kept in mind that considering safety margins for track occupancy determination leads to a further increase of the location inaccuracy, e.g.

- ➔ considering a rollback distance as a safety margin will increase the occupancy extent of railway vehicles mainly determined by ETCS position reports
- ➔ considering a potential TVPS overhang will increase the occupancy extent of railway vehicles mainly determined based on TTD status reports

3.3 Conclusions

Trackbound vehicles moving on the railway network are represented by trackside by determining a corresponding Track Occupancy in the digital representation of the track topology. A Track Occupancy is defined by a position, an extent and an optional safety margin. For safety reasons (e.g. to avoid collisions), the part of the railway track covering a physical vehicle extent can only be used by one vehicle at the same time. The deviation between the Track Occupancy extent (i.e. trackside view) and the vehicle's real physical extent therefore impacts track capacity (e.g. the minimum driving distance).

The analysis of the previous sections outlines that track occupancy is nowadays mainly influenced by the following aspects:

- ➔ TVPS size
- ➔ Frequency of on-board localisation information sent to trackside
- ➔ Latency of communication network
- ➔ Frequency of on-board integrity determination
- ➔ Size of confidence interval, i.e balise location accuracy and travelled distance (distance between balises)
- ➔ Safety margins

It has also been described that correlation and timing issues occur when deriving the Track Occupancy from information of different sources and that the availability of valid train position information on-board is a major prerequisite in order to be able to locate the railway vehicle and to determine the Track Occupancy based on on-board localisation information.

But track capacity is not the only aspect depending on the efficiency and performance of the used localisation technology. It also impacts safety. In order to derive a most accurate view about positions of railway vehicles in the railway network, localisation must ensure that the provided information:

- enables trackside to derive a continuous and complete picture about the position and extent of the railway vehicles (keyword: availability)
- is trustworthy/safe, i.e. the physical occupancy in the railway network corresponds to the track occupancy in the digital image, in other words the physical occupancy must not exceed the virtual track occupancy (keywords: safe front end position and safe rear end position)
- allows a track-selective position determination
- does not "jump" due to temporary sensor errors

More challenging approaches focus on the reduction of track asset costs by using larger TVPS or removing TTD at all. Heading towards a more train-centric approach that is mainly or exclusively based on on-board localisation, on-board localisation accuracy increasingly impacts track capacity, especially in case of errors or degraded situations (e.g. communication loss or train integrity loss) and also safety. In the future, TTD will no more be the central localisation technology but a system out of many simply providing sensory information. If the determination of the Track Occupancy is no more additionally ensured by TTD, this task needs to be taken over by the other involved systems. Safety shifts from trackside localisation systems towards both communication and on-board localisation system. As a consequence, adequate requirements towards the availability and accuracy of these systems need to be derived as a result of a performance and safety analysis.

4 Target Picture

4.1 Strategic Objectives

This chapter describes the long-term objective and the key aspects that are needed in order to fulfil the needs of the railway system of the future considering that information for track occupancy could be provided from the train and from the trackside.

The high-level targets are:

- Decrease the overall Track Occupancy system costs
- Increase capacity on existing lines and reduce the need for infrastructure extension
- Maintain or increase the availability and reliability of the Track Occupancy system
- Maintain or increase the safety of the Track Occupancy system

These targets will be achieved by:

- decreasing the necessary amount of trackside equipment needed for safety purposes
- abstraction of localisation information and increasing the flexibility in solution design
- enabling driving in braking distance with moving block or virtual block interlocking logics
- determining the safe train front and rear positions (through train integrity monitoring system or rear end localization) and providing them highly available to APS
- enhancing the on-board localisation function regarding availability, accuracy and safety
- enhancing the availability and quality of the underlying communication network

The long-term objective requires different obstacles to be solved including the rollout will always happen in sequences and for certain network areas. Therefore, the modularity and upgradability are key factors to be considered and enshrined in the requirements that are generated based on the target picture.

4.2 Reduced dependency on physical trackside infrastructure

In the target picture, the track occupancy of a track bound vehicle can be determined in a flexible train centric approach. This means that track occupancy is mainly determined by onboard information which can be enriched with track side information from TTD if needed. This will allow the system integrator to find optimal solutions for their capacity needs.

In the target picture, trackside shall provide information (e.g. Digital Map, GNSS Augmentation…) to on-board enabling the enhanced on-board localisation function to achieve its optimal performance.

The target picture of the Track Occupancy Function

1. shall use less infrastructure elements (e.g. Eurobalises, track circuits, axle counters) for track occupancy determination
2. Shall be based on radio-based controlled train units, under the assumption of the always connected, always reporting principle.

4.3 Abstraction of localisation technologies

Localisation of physical objects in the railway environment can be performed by different devices and technologies. For example, in today's train operation, physical objects such as trains are located using TTD and/or onboard localisation systems are used for train localisation in the context of CCS. Different technical solutions exist for both TTD and onboard localisation systems.

It is therefore important that track occupancy can be determined and represented in a generic way on the track topology as independent as possible from the localisation technology and the devices used for locating the physical object.

4.4 Driving in braking distance

Today's localisation solutions lack accuracy, availability and integrity (position and velocity have been observed to be outside the confidence interval) to be used as the basis for a moving block or virtual block system. New localisation solutions shall be designed to enable driving in braking distance, so that line and hub capacities can be increased. To achieve this, a frequent reporting of both train front and rear end localisation information to the APS with a high level of accuracy and availability is required.

4.5 Localisation in Track Area

Track occupancy determination shall be able to support all the different operations that require the safe and accurate representation of occupied track segments.

Track occupancy determination is required not just for Track Edge Sections but also for track areas that represent a set of different sections. This is useful when representing, for example, an area where maintenance works are being carried out. The occupation of that track area is effectively translated into the occupation of different segments in the network produced by one originator at the same time.

5 Functional needs towards Localisation

This chapter summarises abstractly the functional needs to determine the track occupancy. Describing requirements is not in the scope of this concept. The listed information are basics for further work on the requirement specification.

To determine the track occupancy, the localisation system TTD, OTD and ETCS onboard shall provide the following information:

- Track Vacancy Protection Section (TVPS) status
- Estimated train front end position and the relevant confidence interval
- track selectivity localisation information
- train integrity information (for full formation status)
- safe train length or safe rear end position and its uncertainty.
- orientation and movement direction
- Train speed

Localisation shall provide these information with high quality for a safe localisation and high accuracy for optimal capacity.

The following chapters address the functional needs of each subsystem providing information required by the track occupancy concept.

5.1 Functional needs from the TTD

- The TTD monitors the vacancy and occupancy of TVP Sections (TVPS). It shall provide the statue of the TVPS.
- When a trackbound railway vehicle is on a TVPS, the TTD system shall report the TVPS state *OCCUPIED*.
- When no trackbound railway vehicle is on a TVPS, the TTD system shall report the TVPS state *VACANT*.

In case the TTD system can’t determine the state (due to a failure, operational conditions…), the TTD system shall report the TVPS state *OCCUPIED*

5.2 Functional needs from OTD

OTD is a feature that onboard systems can be optionally equipped with to provide an accurate location referenced to a specific element of the infrastructure (e;g. RFID reader, balise reader, perception determining specific element in the vicinity of the track …).

The information is suitable to determine specific train location.

5.3 Functional needs from the onboard system

A Train Unit equipped with ETCS and with an onboard localisation system is capable of sending a train position report. This train position report contains data provided by the onboard localisation system and by the train integrity management system.

5.3.1 Functional needs from the onboard localisation system

The onboard localisation system shall provide data parts of the train position report. (See reference to /22E126/ for more detail):

- Reference point ID. Unique identifier of the element from which an estimated distance is given. Comparable to NID_LRBG but not limited to balise technology /Subset-026/, i.e., could be any point on the track edge
- Train orientation. Orientation of the train in relation to the direction of the reference point. Comparable to Q_DIRLRBG but not limited to balise technology /Subset-026/.

- Movement direction. Direction of train movement in relation to the direction of the reference point, i.e., towards or away from the reference point. Comparable to Q_DIRTRAIN but not limited to balise technology /Subset-026/.
- Position qualifier. It tells on which side of the reference point the estimated train front end position is. Comparable to Q_DLRBG but not limited to balise technology /Subset-026/.
- Estimated distance. Distance along the track between the last relevant reference point and the estimated train front end position. Comparable to D_LRBG but not limited to balise technology /Subset-026/.
- Underestimation of the estimated distance. The safe distance along the track the train may have travelled further than the estimated train front end position. Comparable to L_DOUBTUNDER but not limited to balise technology /Subset-026/.
- Overestimation of the estimated distance. The safe distance along the track the train may have travelled shorter than the estimated train front end position. Comparable to L_DOUBTOVER but not limited to balise technology /Subset-026/.
- Track edge id. Identifier of the track edge on which the estimated train front end position is located. By using a digital map, the parameters “train orientation” and “position qualifier” can be derived based on the “reference point id” and the “track edge id”. Only populated if system is using a digital map based on a node/edge-model.
- Map reference data. Map parts validated by LOC-OB that cover the area between the min safe train front end position and the max safe train front end position. Map reference data is defined in [RCA.Doc.59]. Only populated if system is using a digital map.
- Train front end safety property. This output, considering the train integrity and the train composition definition data, will determine whether the localisation information can be considered safe or non-safe.
- Validity timestamp. Time stamping of the output, i.e., the time when the localisation information was valid. Rationale: Needs to be safe to help consumers to decide on freshness of information.
- System status. Health of the system function and its output information
- Estimated train speed. Absolute (1D) estimated speed value along the track, referred to the vehicle where the LOC-OB is installed.
- Underestimation train speed. The safe upper bound of the speed of the vehicle where the LOC-OB is installed.
- Overestimation train speed. The safe lower bound of the speed of the vehicle where the LOC-OB is installed.
- After powering on the onboard localisation system, the system shall be initialised by itself with no human help.

The onboard train localisation system may use new technologies supported by a Digital Map, Augmentation data.

5.3.2 Functional needs from the onboard train integrity management system

The train integrity management system is an onboard system capable of determining the train integrity information.

- If no split of some parts of the Train Unit occurs, the train integrity management system shall report the information train integrity confirmed.
- When a failure or a specific train operation occurs leading to a split of some parts of the train, the train integrity management system shall report the information train integrity lost. In this case the safe train length could not be considered anymore.
- In case of failure or impossibility to determine the train integrity information, the train integrity management system shall report no train integrity available.

This information is used in conjunction with the train length (data known as a train data parameter or entered by the driver) to determine the safe train length.

6 Operational Setting

For deriving functional and non-functional requirements for localisation function, operational settings for track-bound railway vehicles are defined. These will include both regular operations and operations in degraded situations, where one or several components of the RCA system are not functioning in the intended way. For each setting the impact on the localisation system is described. In this stage only a qualitative assessment is made. For a quantitative assessment a capacity analysis of the overall system needs to be carried out. Note that the stated accuracy impacts are to be understood as along track accuracies. Localisation profile definition and performances are under analysis and will be provided in a next release.

Table 4: Regular Operational Setting

No.	Setting Description	Speed profile	Remarks	Area affected	Impact on Localisa-tion
	En Route (A train is travelling between planned stops.)				
	High Speed – High Density Line	Above 0 km/h and up to 500 km/h	Minimum Headway Time: Below 120 s	Any	High accu-racy needed
	High Speed – Low Density Line	Above 0 km/h and up to 500 km/h	Minimum Headway Time: Above 120 s	Any	Low accu-racy needed
	Low Speed -High Density Line	Above 0 km/h and up to 160 km/h	Minimum Headway Time: Below 120 s	Any	High accu-racy needed
	Low Speed -Low Density Line	Above 0 km/h and up to 160 km/h	Minimum Headway Time: Above 120 s	Any	Low accu-racy needed
	Clearing a level crossing	Above 0 km/h and up to to 160 km/h	Maximum closure time: 150s	Any	Medium accuracy needed
	Clearing a standard point area	Any	Maximum re-lease time: 2s	standard point area	Same as line
	Clearing a critical point area	Any	Maximum re-lease time: 0.5s	critical point area	High ac-cu-racy needed
	Stopping (A train is coming to a halt at the EoA)				
	Stopping at a buffer stop	10 km/h down to 0 km/h		Track seg-ment be-fore a buffer stop	High accu-racy needed

No.	Setting Description	Speed profile	Remarks	Area affected	Impact on Localisation
	Stopping at a defined location	10 km/h down to 0 km/h		Predefined points on the line, e.g: platforms, level crossings	High accuracy needed
	Stopping at a non-defined location	10 km/h down to 0 km/h		Any point on the line, stopping point not critical for operation	Medium accuracy needed
	Stabled **(A train has stopped and is not in operational use)**				
	Parked with connection (The train is parked and has a connection to the track side, train sends TPRs)	0 km/h		Station, shunting area, depot, siding	Medium accuracy needed, LOC-OB needs to be active
	Parked without connection (The train is parked and has no connection to the track side)	0 km/h		Station, shunting area, depot, siding	Medium accuracy needed, TTD needs to be available
	Shunting **(Making and dividing trains, moving vehicles between shunting areas or to stations)**				
	Shunting	Speed Profile: 0 km/h up to 40 km/h		Areas that are allowed for shunting by national regulations	Medium accuracy needed, change of direction needs to be identified
	Coupling and Splitting				
	Approach to a vehicle to be coupled (A train unit approaches another train unit to be coupled to form one train, this, if	10km/h down to 0 km/h	Solving overlapping track occupancy is a mission of	Station, shunting area	None

No.	Setting Description	Speed profile	Remarks	Area affected	Impact on Localisation
	TTD exists, typically involves entering an occupied track)		the APS and out of scope for this document.		
	Splitting (A train Unit is split into two independent train units)	10km/h down to 0 km/h	Solving overlapping track occupancy is a mission of the APS and out of scope for this document.	Station, shunting area	None
	Start up – to be discussed				
	Start of mission from power down	0 km/h	Time to mission start has to be defined		Time to first valid position from cold start has to be defined
	Start of Mission from power up	0 km/h	Time to mission start has to be defined		Time to first valid position from warm start has to be defined

Table 5: Operational settings

Table 6: Degraded Operational Setting

No.	Setting and Description	Remarks	Affected regular operational setting	Impact on Localisation
	No Localisation Information available for Track Occupancy determination			
	Degraded communication between onboard and trackside (The connection between onboard system and trackside system is degraded, therefore no or limited on-board localisation information can be transmitted to the trackside.)	This setting has to be resolved by APS.	All but Parked without connection	none
	On-board Localisation unavailable (No safe position can be generated onboard. The onboard localisation system does not send localisation information to the onboard and trackside systems.)	This setting has to be resolved by APS and VS.	All	Availabilty requirement for LOC-OB to be defined
	Loss of Train Integrity			
	Accidental splitting of a train (A part of the train has decoupled from the rest of the train.)	This setting has to be resolved by APS	Stopping, Shunting, Coupling and Splitting	If done wih TIMS: Change of TIMS status, Time to alert has to be specified, If done with MOL: none If done with TTD: none
	TIMS information not available at trackside (The TIMS is not available, therefore a loss of integrity has to be assumed)	This setting has to be resolved by APS	Stopping, Shunting, Coupling and Splitting	none

Table 7: Degraded Operational Settings

7 Track Occupancy System Overview

7.1 System Level of Track Occupancy Concept

Track occupancy determination has to be able to interface many different subsystems within RCA (and potentially beyond) with minimal interdependency.

The following Figure 15 is a solution overview of this concept. It describes abstractly the needed function for the Track Occupancy. The used functions are according to the RCA System definition /RCA.Doc.35/.

The function inside the System boundary are scope for defining the solution in further works.

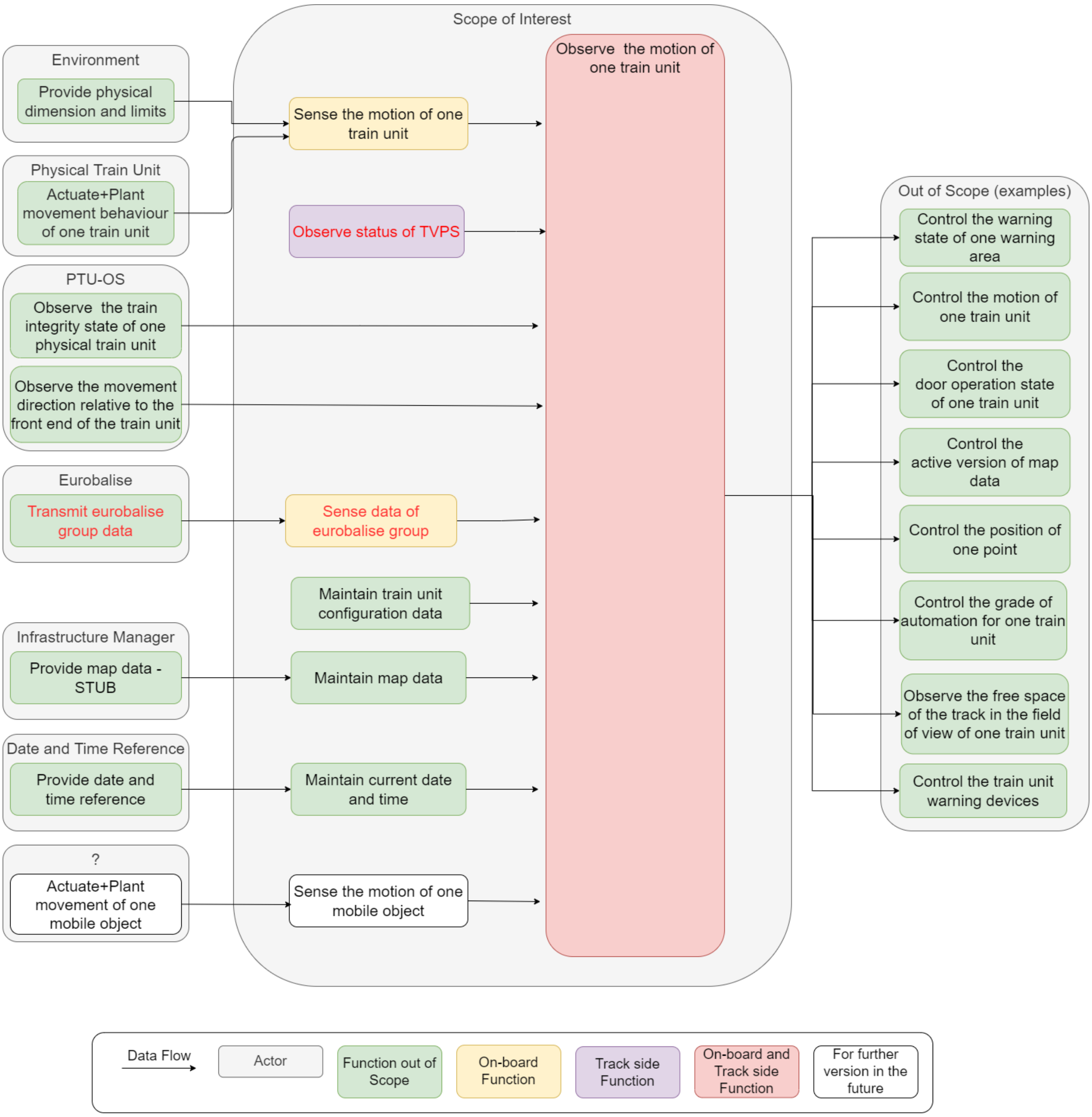


Figure 15: System Layer of Track Occupancy Concept

The following function provides input information:

- "Sense the motion of one train unit" is used for sensor input to observe the position of a train unit.

- “Sense the data of eurobalise group” updates the reference coordinate system for positioning of the train unit front end.
- “Maintain train unit configuration data” provides consistent train unit configuration data for all relevant function of the system.
- “Maintain map data” provides consistent map data for all relevant function of the system and changes map data.

The function “Observe the motion of one train unit” receives the provided information and provides output informations to the following functions:

- “Control the motion of one train unit” controls the motion state of a train to fulfil the non-functional requirements (especially safety, reliability, availability and performance).
- “Control the motion of one point” controls the motion state of a point to fulfil the non-functional requirements (especially safety, reliability, availability and performance).

Outside the System boundary and consequently out of scope for defining the solution are following functions:

- “Physical dimensions and limits presence” provides present actual output in filed of view of one train unit, which can be used for the extent of on train unit on the track.
- “Actuate+Plant movement behaviour of one train unit” provides actuation of traction and brake effort to achieve the train unit motion.
- “Observe the train integrity state of one physical train unit” estimates the integrity state of a physical train unit based on inputs from multiple sensors on the train.
- “Transmit eurobalise static information” represents the data transmission from a Eurobalise (EUB) to a train unit. This function can be used for location references in the Track Occupancy Concept.

In the following table are the System function spilt in to logical functions and the Subsystem which realises the functionality. The red coloured functions are proposals for the RCA model from this Concept.

System function	Logical function	Subsystem RCA constituents
Observe the motion of one train unit	Estimate the front end position of one train unit with respect to reference	LOC-OB
	Estimated the orientation of one train unit with respect to reference	LOC-OB
	Estimate the movement direction of one train unit with respect to reference	LOC-OB
	Estimate the acceleration of one train unit	LOC-OB
	Estimate the velocity of one train unit	LOC-OB
	Estimate the safe train length/rear end of one train unit	LOC-OB/ TIMS/ DAC
	Calculate the observe state of one train vacancy protection section	TTD
	Calculate the observed state of one trackbound moveable object	APS
	Estimate position qualifier	LOC-OB

	Calculate position confidence interfal for determined position	LOC-OB
Sense the motion of one train unit	Measure the velocity of one train unit	LOC-OB
	Measure the angular velocity of one wheelset	LOC-OB
	Measure the acceleration along track of one train unit	LOC-OB
	Measure data from RFID reader	OTD
	Detect the 3D objects in field of view of of one train unit	OTD
Sense the data of one eurobalise	No further split	LOC-OB
Observe the train integrity state of one physical train unit	No further split	TIM

Table 8: System function with related Logical functions and Subsystems

The realised Subsystem for the system and logical functions are described in the following chapters.

7.2 Localisation Subsystems

This chapter gives an overview of Localisation Subsystems that exist already today or are under development. These subsystems are able to perform Logical Functions from the previous section 7.1. For each subsystem, a short outlook on potential future changes is given.

7.2.1 Trackside train detection systems (TTD)

TTD systems are widely used today for Train Protection systems . Note that from todays TTD, train identification information and train speed are not available. Therefore not all information required for Track Occupancy determination specified in section 3.2 is available and must be derived by other means if possible. The localisation accuracy depends on the length of the TTD segments and the time delay between track occupancy and TTD output.

Pros: Proven technology, no airgap (increased robustness), mitigation against failures such as radio interruption or train integrity device out of order, facilitating migration strategy because they allow mixed traffic including trains not yet equipped by train integrity or safe train length.

Cons: Costly to implement and maintain especially if high accuracy is needed, incomplete information, Reduced number of detectable objects (see chapter 3.2.3.1), Oversized Occupancy extent (see chapter3.2.3.2), Undetected Overhang (see chapter 3.2.3.3).

Outlook: There are ongoing trials with fibre optic sensing (FOS) as an alternative to existing technology solutions. FOS has the potential to reduce implementation costs and additionally to deliver train speed. Furthermore, RFID tags on trains can be read out from the trackside and provide location and train identification information.

7.2.2 Localisation Onboard (LOC-OB)

Onboard localisation is mainly used in radio-based ETCS today. The system today consists of a Eurobalise transmission module (BTM) and an odometry system which measures the distance travelled since the last relevant balise group. Details about the output of this Subsystem can be found in chapter 5.2.

Pros: Proven technology, localisation accuracy can be specified by the infrastructure manager by adjusting the Eurobalise density.

Cons: Balises are expensive to install and maintain, they can cause undue braking and delays due to failures. Today’s odometry shows performance issues due to slip and slide or other effects that result in poor accuracy.

Outlook: Onboard localisation can be improved using new types of sensors such as GNSS and inertial navigation. The inclusion of digital map data and GNSS augmentation information will increase accuracy and availability by means of the use of new localisation methods and technologies when using 3D positioning. Time synchronisation and reduction of communication latency will help to reduce the inaccuracy due to transmission delay uncertainties.

7.2.3 Train Integrity Monitoring System (TIMS)

Train integrity monitoring is crucial for operations without TTD. Today TIMS is not used in operation although modern passenger trains are able to determine their integrity status. The main challenge is to retrofit old freight trains with TIMS. TIMS allows the calculation of the safe train length. A detailed description of the safe train length calculation can be found in chapter 3.2.4.1~~.~~ The knowledge of the safe rear end location of a train is needed to enable moving or virtual blocks,

Outlook: Even if this document does not aim to provide a solution for determining train integrity, for reading comprehension different possible solutions are listed. These must be taken as examples and not definitive proposals. The introduction of digital automatic couplings could provide a train integrity status for freight trains. For trains with locomotives in the front and rear or with a control car, typically two onboard localisation systems are available and could be used to provide a train integrity status. Another solution is the use of a train end device which localises the train rear end, so that by combining train front and rear end information a train integrity status can be derived. The train end device could be considered as a type of MOL.

7.2.4 Mobile Object Locator (MOL)

The MOL is the localisation system used to localise trackbound movable objects such as wagons, cranes or excavators. It can also be used to localise one end of a train (see TIMS). Using this localisation information, the trackbound movable object extent of the localised vehicle can be determined.

Outlook: The MOL is envisioned to be a lower cost version of the LOC-OB with reduced performance requirements but based on similar technology. Research on MOLs has been started at SBB within the SmartRail 4.0 program.

7.2.5 Person Supervisor and Locator (PSL)

The PSL is the future localisation system that is currently envisioned to be used for localising authorised staff. Today, to our knowledge, no PSL is used in operation.

Outlook: The PSL is envisioned to be a low-cost, light-weight device that can be carried by the authorised staff when they work on the railway track; a version of the LOC-OB with reduced performance requirements but based on similar technology. Research on MOLs has been started at SBB within the SmartRail 4.0 program.

7.3 Implementation scenarios of subsystem compositions

The following Figure 16 gives an overview of the allocation of logical components from section 7.1 to the subsystem from chapter 7.2. There are some Logical Components in Figure 16 which are not allocated to Subsystems (green box). The allocation of these Logical Components is not within the focus of this paper and therefore omitted to simplify the figure. What is known so far is that they are not located on-board of a Train Unit but on trackside.

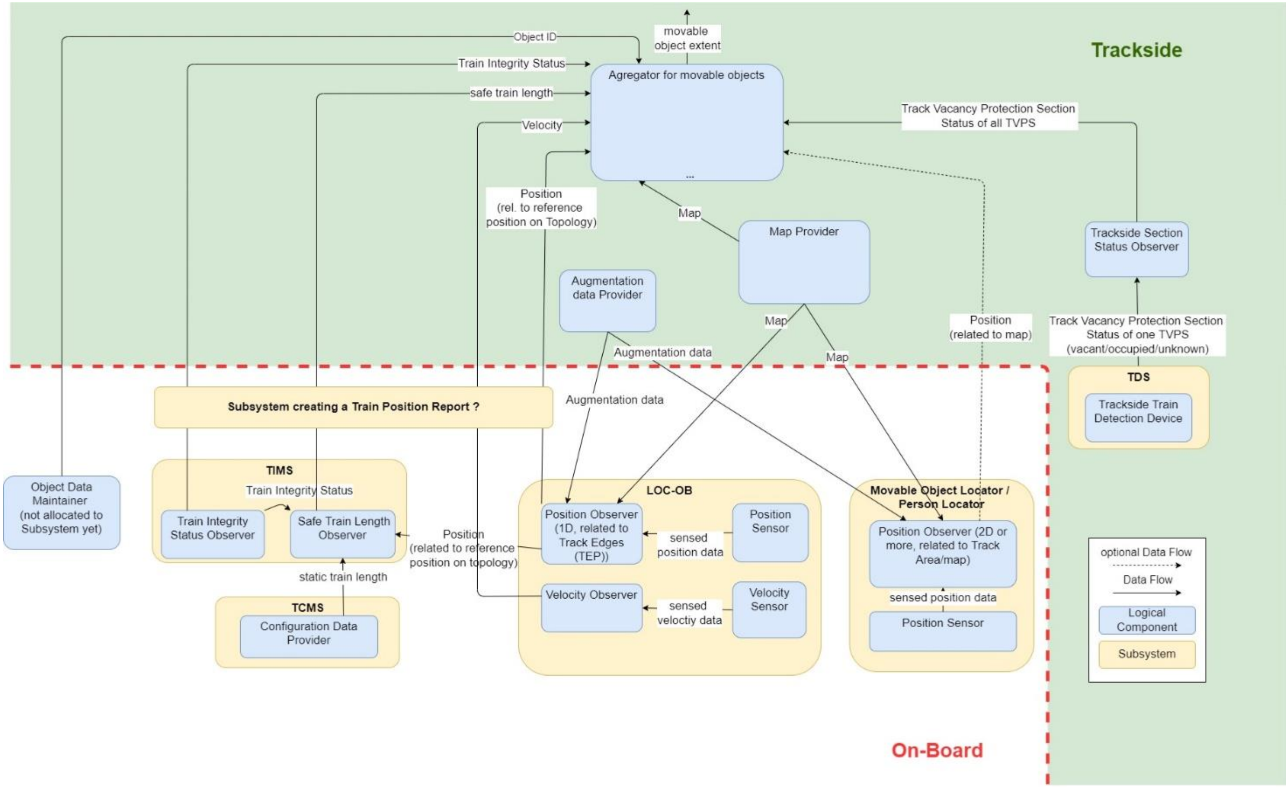


Figure 16: Allocation of Logical Components to Subsystems

The Logical Component *Position Observer* (allocated to MOL/LOC-OB) requires certain information from the trackside systems as an input. This supporting information includes digital map, time synchronisation and augmentation data (for GNSS and other onboard sensors). The definition of the digital map data and interfaces is currently done in the RCA Digital Map cluster refer to /RCA Doc 59 Digital Map System Definition/. Specification of needs for time synchronisation information and augmentation data is currently under way in the localisation working group and will be addressed in separate documents.

The onboard localisation system (LOC-OB) provides position, velocity and time to the APS.

The need for time synchronisation is not displayed in *Figure 16*, since it would result in a loss of readability. Trackside and on-board information should use a synchronised time for their communication.

Today different implementation scenarios can be deployed depending on the existence of TTD or not, and the localisation equipment installed in the onboard. Hence, five different scenarios have been identified, depending on the available onboard and trackside equipment. The following subchapters list those scenarios.

7.3.1 Scenario 1

This scenario considers only Trackside Equipment. The scenario is listed for completeness only and is not within the Target picture of this paper.

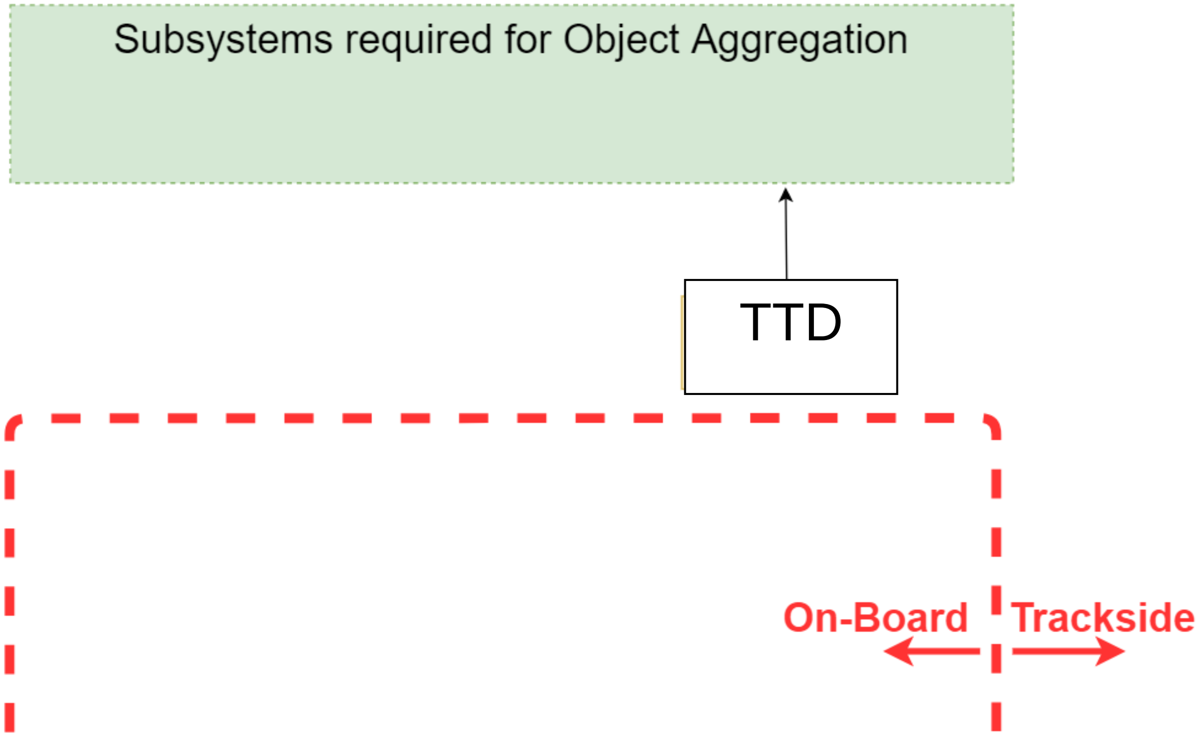


Figure 17: Scenario 1

The determination of Track Occupancy for this scenario is described in chapter 3.2.1.

7.3.2 Scenario 2

In this scenario the trains are equipped with a LOC-OB unit that allows detection of the Train Unit Front end. The TTD is available on the trackside. A combination of Train Unit localisation information (Train Position Report - TPR) and Trackside information (TVPS states) can be performed to determine Track Occupancy. The LOC-OB gets supporting information from trackside to enhance train localisation information that is provided to the trackside by means of a TPR as is depicted in Figure 2.

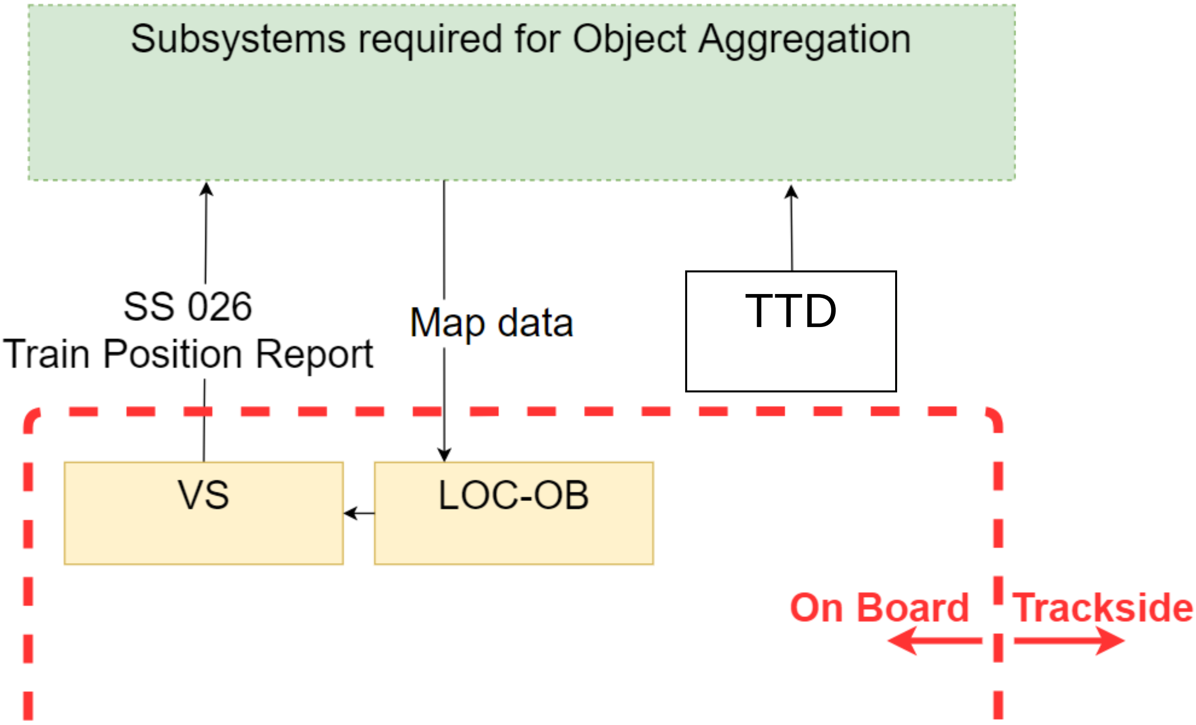


Figure 18: Scenario 2

The determination of Track Occupancy for this scenario is described in section 3.2.4.3

7.3.3 Scenario 3

This variant has a LOC-OB on the Train Front End and a second LOC-OB on the Train Unit Rear End available. Front and rear end position are combined to determine the Track Occupancy of the Train Unit. For this scenario it is not yet clear how the rear end information would be communicated from Train to Trackside (dotted lines).

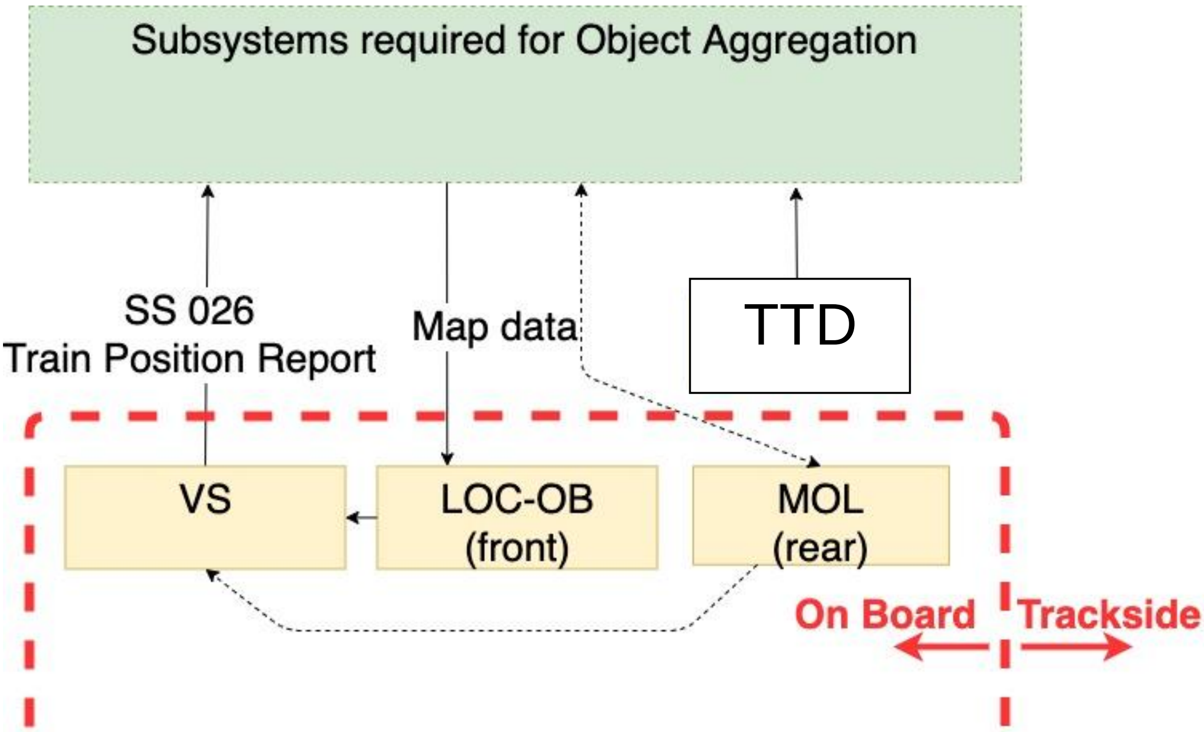


Figure 19: Scenario 3

To enable data exchange between *Trackside Subsystems for Object Aggregation* and LOC-OB/MOL (rear), an interface is needed, which is nowadays is not defined. Without this interface the Logical Component *Position Observer* (in the Subsystems LOC-OB/MOL) cannot achieve the necessary requirements to determine track occupancy.

The determination of Track Occupancy for this scenario is described in section 3.2.4.3.2.

7.3.4 Scenario 4

In this scenario Track Occupancy is determined without any Trackside Train Detection (TTD) system. All information that are required for determining the Track Occupancy, can be provided with the position report. The position report consists among other information of Train Integrity, safe Train Length and Train Location information. Details about the Position Report are described in chapter 3.2.4.1. Again, the information flow from the trackside to the LOC-OB consists of supporting information.

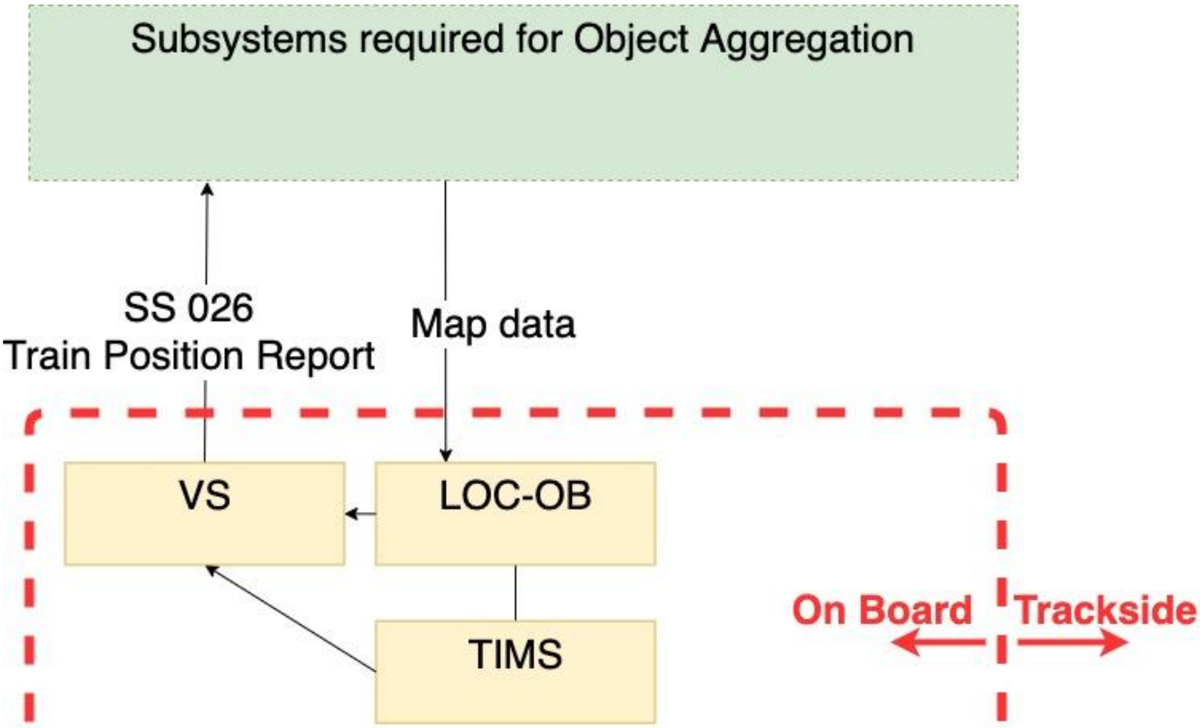


Figure 20: Scenario 4

The determination of Track Occupancy for this scenario is described in section 3.2.4.

7.3.5 Scenario 5

This is similar to Scenario 4 (see chapter 7.3.4) with supporting Trackside Train Detection. Section 3.2.4.3.2 describes some examples where the combination of Trackside and on-board localisation data improve capacity of the railway network.

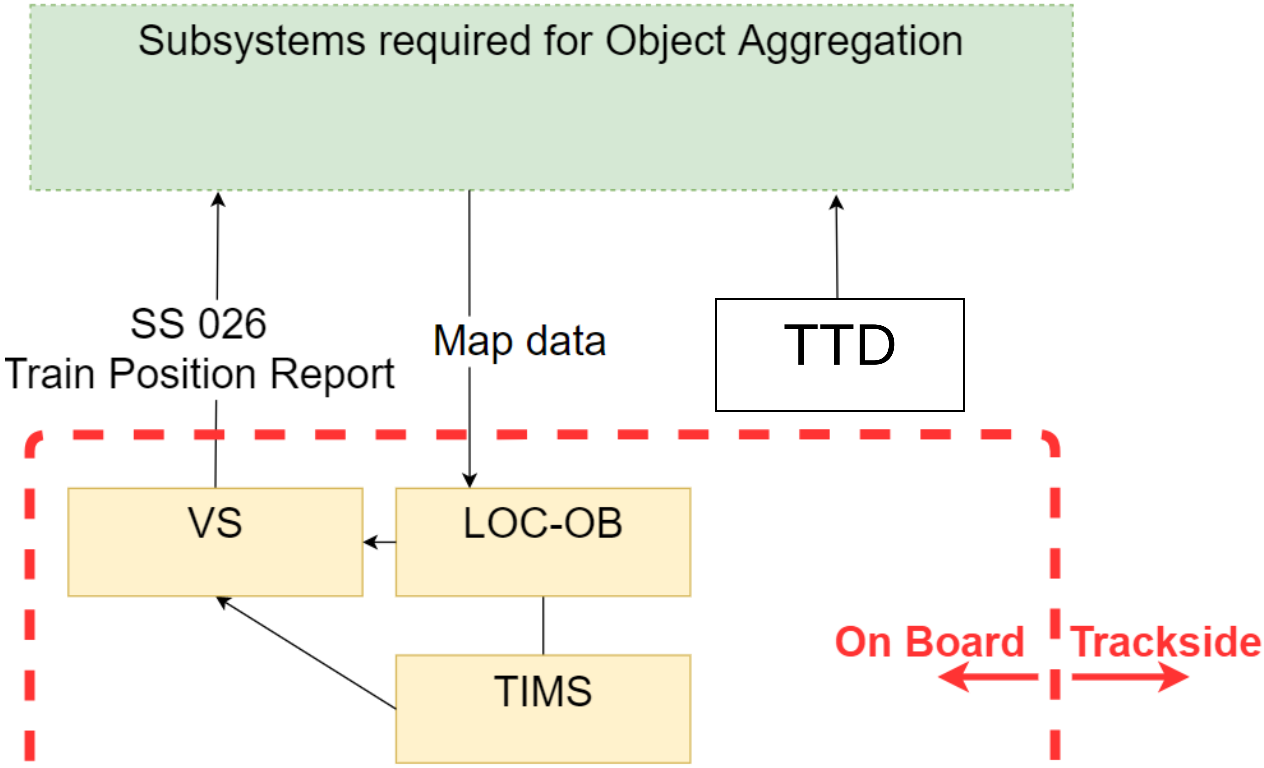


Figure 21: Scenario 5