X2Rail-5

Project Title:	Completion of activities for Adaptable Communication, Moving Block, Fail Safe Train Localisation (including satellite), Zero on site Testing, Formal Methods and Cyber Security
Starting date:	01/12/2020
Duration in months:	30
Call (part) identifier:	S2R-CFM-IP2-01-2020
Grant agreement no:	101014520

Deliverable D4.3
Report for Moving Block Demonstrators

Due date of deliverable	Month 24
Actual submission date	06-Dec-2022
Organization name of lead contractor for this deliverable	SMO
Dissemination level	PU
Revision	Final

This project has received funding from Shift2Rail Joint Undertaking (JU) under grant agreement 101014520.The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Shift2Rail JU members other than the Union.

Authors & Version Management

Authors	**TD, STS, SMO**
Contributors	Thales (TD)
	Hitachi (STS)
	Siemens (SMO)

Version Management		
Version Number	**Modification Date**	**Description / Modification**
01	15-Sep-22	First outline version
02	18-Oct-22	First version incorporating results
03	18-Nov-22	Further update, include Executive Summary, Conclusions
04	18-Nov-22	Clean version of 03 for TMT/SC review
05	06-Dec-22	Updated for release after TMT/SC review
06	06-Dec-22	PDF version for release to JU

Executive Summary

Much of the work in X2Rail-5 WP4 Moving Block has been to prepare the updated Moving Block Specification, D4.1, based on the previous version created during X2Rail-3 [X2R3D42].

However, in addition to the work on the Moving Block Specification, three separate Moving Block Technical Demonstrators have been developed. This deliverable is a report the three Moving Block Technical Demonstrators.

The three Moving Block Technical Demonstrators were developed by different suppliers, as in the following table:

Task	Demonstrator	Supplier
Task 4.5	High Speed Line	Thales (TD)
Task 4.6	Low Traffic	Hitachi (STS)
Task 4.7	Urban / Suburban	Siemens (SMO)

The Moving Block Technical Demonstrators were developed based on the Moving Block Specification from X2Rail-3 [X2R3D42].

There is a separate section for each of the Moving Block Technical Demonstrators, giving descriptions of the architectures, lists of the scenarios tested, and description of results. The descriptions of results include problems detected, and proposed solutions.

The results have been used to improve companion deliverable, D4.1, which is the updated Moving Block Specification from X2Rail-5.

Finally, this deliverable contains an overall Conclusions section, which concludes that is has been possible to realise the L3 Trackside system specified within the Moving Block Specification from X2Rail-3 [X2R3D42], albeit with some detailed issues to be resolved, as might be expected when implementing such a system.

Table of Contents

Table of Figures

Table of Tables

Abbreviations and acronyms

Abbreviation / Acronyms	Description
CRE	Confirmed Rear End for a train, derived from Train Position Report
CTC	Central Traffic Control
DMI	Drive Machine Interface
EoM	End of Mission
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
FS	Full Supervision – Mode in ETCS
FVB	Fixed Virtual Block
HMI	Human Machine Interface
HSL	High Speed Line
IXL	Interlocking
L2	ETCS Level 2
L3	ETCS Level 3
L3 Trackside	The Trackside component of an ETCS Level 3 signalling system
MA	Movement Authority
MSFE	Max Safe Front End for a train, derived from Train Position Report
mSFE	Min Safe Front End for a train, derived from Train Position Report
MSRE	Max Safe Rear End for a train, derived from Train Position Report
mSRE	Min Safe Rear End for a train, derived from Train Position Report
NTC	National Train Control – Level in ETCS
OBU	On-Board Unit
OS	On-Sight – Mode in ETCS
PR	Position Report
RBC	Radio Block Centre
SB	Standby – Mode in ETCS
SMO	Siemens Mobility
SoM	Start of Mission
SR	Staff Responsible – Mode in ETCS
STS	Hitachi
TD	Thales
TL	Train Location – concept within L3 Trackside as described in [X2R3D42]
TMS	Traffic Management System
TMS-PE	TMS Plan Execution layer
TPR	Train Position Report
TRL	Technology Readiness Level
TS	Track Status – consolidation of Track Status Areas, as described in [X2R3D42]
TSA	Track Status Area – concept within L3 Trackside as described in [X2R3D42]
TTD	Trackside Train Detection, either Track Circuits or Axle Counters
WP	Work Package

1 Introduction

This document forms X2Rail-5 Deliverable D4.3 Report for Moving Block Demonstrators.

There are three Moving Block Demonstrators within X2Rail-5 WP4:

1) Task 4.5 Moving Block Technical Demonstrator 1 for High Speed Line
2) Task 4.6 Moving Block Technical Demonstrator 2 for Low Traffic
3) Task 4.7 Moving Block Technical Demonstrator 3 for Urban/Suburban

Each of these Technical Demonstrators has been created by a different supplier, as shown in Table 1:

Task	Demonstrator	Supplier
Task 4.5	High Speed Line	Thales (TD)
Task 4.6	Low Traffic	Hitachi (STS)
Task 4.7	Urban / Suburban	Siemens (SMO)

Table 1: Moving Block Technical Demonstrators

This deliverable is a single Report covering all three Moving Block Technical Demonstrators.

The Moving Block Technical Demonstrators are based on the results from X2Rail-3, in particular X2Rail-3 deliverable D4.2 Moving Block Specifications [X2R3D42].

There is a separate section for each Moving Block Technical Demonstrator, and a final section with overall Conclusions.

Where there are references to specific requirements, they are formatted, for example:

REQ-TrainLoc-5

REQ-TTD-3

These are references to the requirements in X2Rail-3 deliverable D4.2 Moving Block Specifications [X2R3D42].

2 Task 4.5 Technical Demonstrator 1 for High Speed Line

2.1 Objective

The purpose of this task is to demonstrate that the key principles for Level 3 developed in X2Rail-3 WP4 and being refined as part of this work package can be implemented for a Full Moving Block system with Trackside Train Detection and that the desired operation for a High Speed Line (HSL) can be achieved.

2.2 Architecture and Environment

The Thales ETCS L3 Trackside HSL demonstrator implements a selected subset of requirements of the System Specification [X2R3D42], configured in accordance with the Engineering Rules and tested in a Test and Simulation environment.

Figure 1 outlines the architecture of the demonstrator:

- The L3 Trackside component represents a prototype which includes functionality traditionally considered part of the interlocking as well as the RBC functionality and runs in a target environment.
- The ETCS On-board and trackside equipment (e.g. TTD) is simulated (Test and Simulation System).
- The CTC simulates a TMS-PE (Plan Execution) layer and interacts with L3 Trackside to guide the trains through the network.
- HMI provides visualisation of the system.

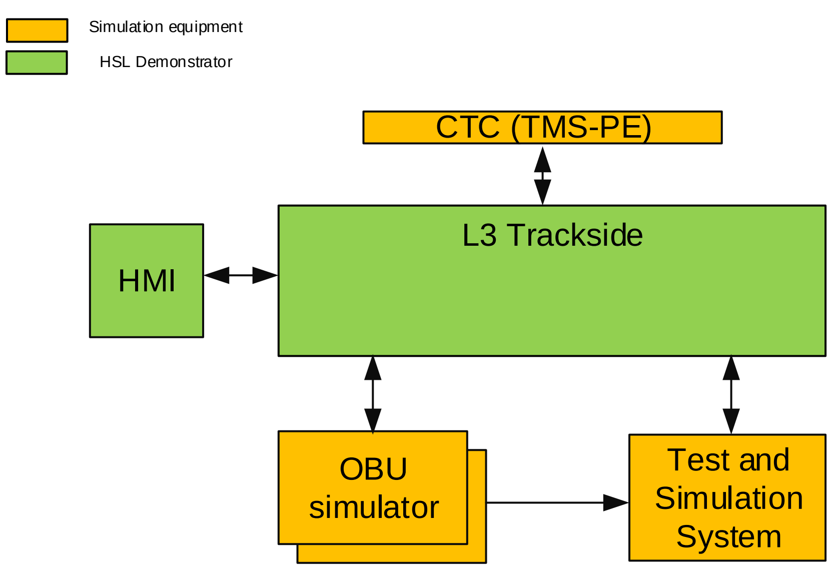

Figure 1: HSL Demonstrator Architecture

2.3 Demonstrated Scenarios

The test scenarios represent the operational scenarios to demonstrate the ability of the current specifications to support normal as well as degraded operation for a L3 HSL.

The following scenarios were tested:

1) Track Initialisation: Trackside Initialisation with TTD information and without Dispatcher interaction.
2) Start of Mission (SoM)/End of Mission (EoM): A train performs EoM and thereafter SoM using L3 Trackside stored information.
3) Splitting: After EoM the train physically splits, and the two resulting trains execute the SoM procedure.
4) Normal Train Movement: One train following another train, both trains with Train Integrity Confirmed by external device.
5) Loss of Integrity: Reporting integer train losing and subsequently regaining integrity.
6) Loss of Communications: Integer train losing communication with L3 Trackside and subsequently regaining it.
7) Release of Points: First train crosses and clears points. Afterwards the second train crosses the points and goes to another track.
8) Sweeping: A train sweeps an Unknown Track Status Area.

2.4 Dissemination

Thales provided a video to give an overview of the HSL demonstrator showing the test environment and the executed scenarios. WP members were given the opportunity to raise questions and to pause or re-play the video to facilitate the understanding of the underlying implementation.

The demonstrator provided several views to visualize different system aspects and to verify the expected system behaviour. The track, the trains and the extents of the Movement Authority were visualised and dynamically updated as well as the concepts from the X2Rail-3 Moving Block System Specification like Train Location and Track Status.

2.5 Results and Conclusions

2.5.1 Railway Type

The HSL from Altdorf up to Castione in Switzerland was selected for the demonstrator. This line contains the Gotthard Tunnel and, three stations. The track length is 493 km, containing 550 points and 940 track sections. The test runs were executed on the section between Biasca/Osogna and Castione including the stations. The track length of this section is approximately 20 km and is equipped with ETCS L2 and used by passenger (train length of 400 meters) and freight trains (train length of 400 meters).

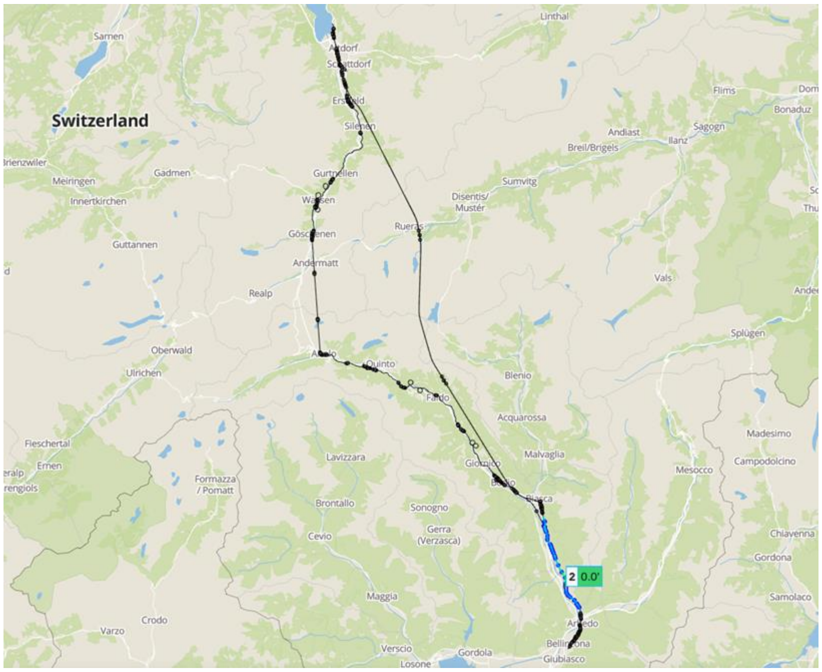

Figure 2: Overview of the HSL

2.5.2 System Type

The system type is Moving Block with TTD. For the demonstrator the original engineering has been used. I.e. the TTD section engineering was not changed.

2.5.3 Results

In order to support the verification of the demonstrator behaviour in respect to the System Specification [X2R3D42] the following view depicting the key concepts was developed. The following figure of the demonstrator shows the key concepts based on the X2Rail-3 specification for the scenario normal train movement of two trains

.

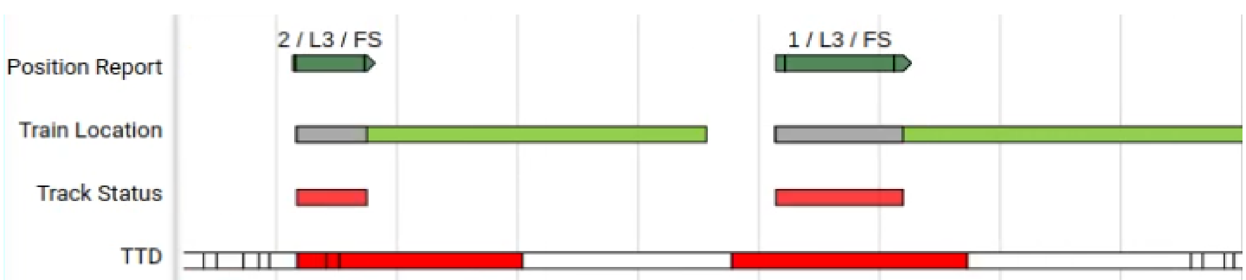

Figure 3: Normal Train Movement scenario

The view shows layers each displaying different information:

- The Position Report layer shows the information contained in the Train Position report.

- Information displayed in the Train Location layer is based on the corresponding Train Location (grey) and Reserved Status (green).
- The Track Status layer shows the Consolidated Track Status.
- The TTD layer shows the L3 Trackside view of the TTD status.

Note: The track itself is displayed in another view during the video (see Figure 2: Overview of the HSL).

The following figure shows the same view during the Start of Mission/End of Mission scenario in which parts of the Track Status are Unknown.

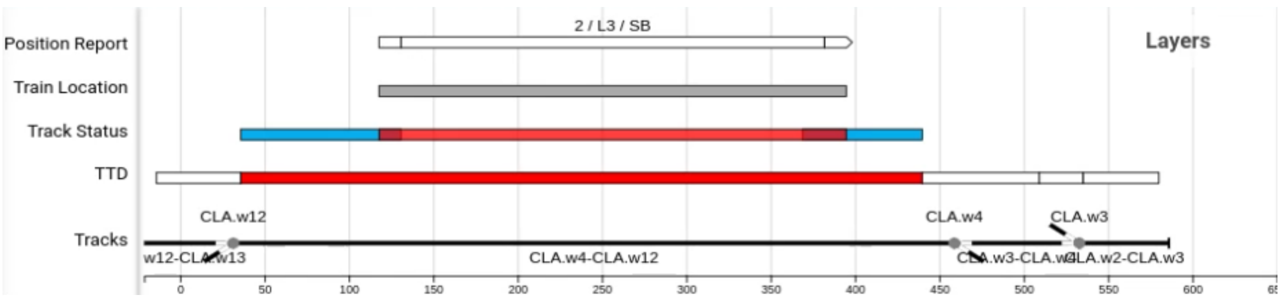

Figure 4: Start of Mission scenario

2.5.3.1 Train Location: TTD information is used as input for the Train Location

2.5.3.1.1 Problem description

According to the System Specification [X2R3D42] to establish the Train Location only information from the position report (CRE, MSFE) is used and for the Track Status Areas assigned to the train additionally TTD information is used. As the Train Location is a concept intended to determine the location of the train using the available information, this approach could lead to inconsistencies, e.g. in the following examples.

2.5.3.1.2 Example:

Let us assume that there is a train in FS, OS regularly sending position reports.

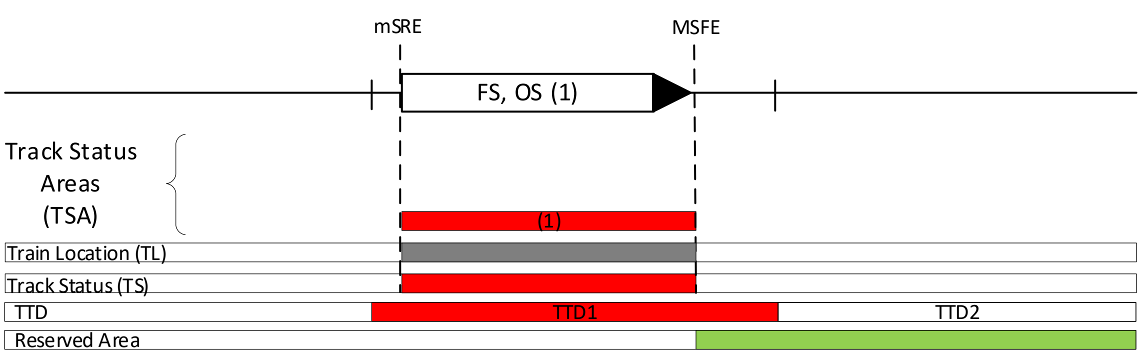

Figure 5: Train Location from TTD – Step 1

Then the train (e.g. due to a short connection interruption) does not report any position report anymore. Then the train moves further forward leading to an occupation of TTD2. Neither the Train Location nor the Track Status is updated.

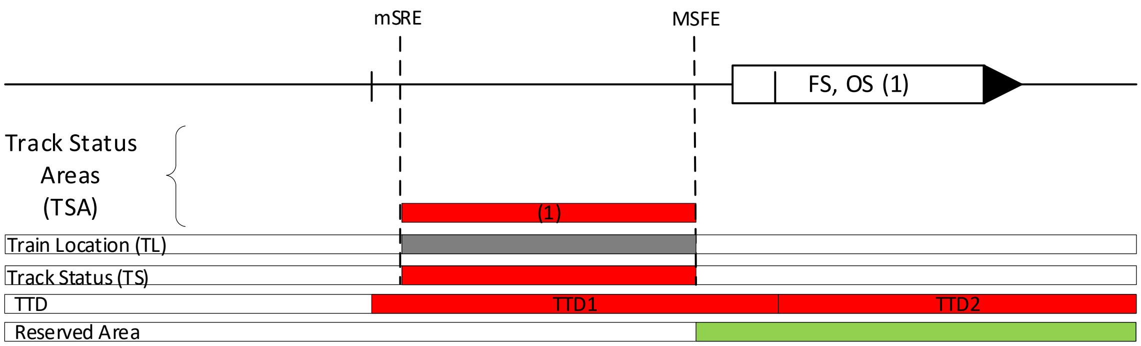

Figure 6: Train Location from TTD – Step 2

Then TTD1 becomes 'Clear'. As the MSRE is still located on TTD1, the Track Status is not updated according to REQ-TTD-3. As a result, the complete Train Location and complete Track Status Area assigned to the train are located in a Clear TTD. This prevents that another train can follow this train closely.

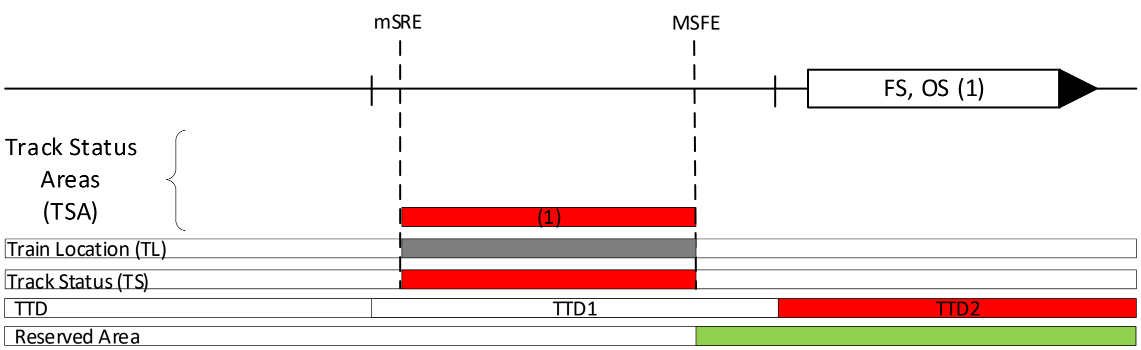

Figure 7: Train Location from TTD – Step 3

2.5.3.1.3 Proposal

The Train Location shall also dependent on TTD information to ensure that inconsistencies as depicted in the problem description above cannot occur.

2.5.3.2 Train Location: Non-integer trains (without a TIMS) not considered.

2.5.3.2.1 Problem description

The requirement REQ-TrainLoc-3 in [X2R3D42] states the following:

The L3 Trackside shall consider the Train Location to be from the Max Safe Front End to the Confirmed Rear End of the train

According to REQ-TrainLoc-5 when a train without a TIMS performs Start of Mission no Train Location is established as there is no CRE for a train without a TIMS.

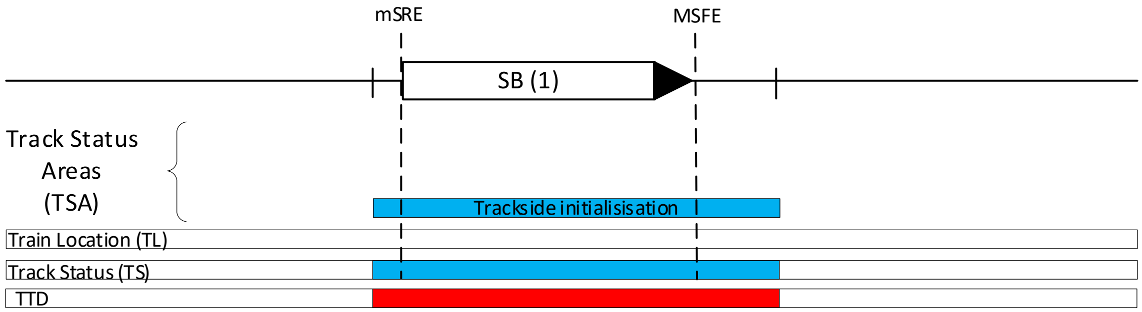

Figure 8: Train Location Non-Integer Train

Without a Train Location, it is also not possible to establish an (Unknown) Track Status Area for this train. Without a Track Status Area assigned to the train other requirements related to Track Status cannot be applied, e.g. extending the Track Status Area due to expiration of the mute timer, etc.

2.5.3.2.2 Proposal

Establish Train Location also for trains without a TIMS using mSRE, TTD information, etc.

This would also allow to apply to other requirements e.g. REQ-TrackStatus-16 for trains without a TIMS. There is no necessity to restrict REQ-TrackStatus-16 only for trains with a confirmed train integrity.

2.5.3.3 Train Location: CRE is also established for trains not in L2/FS, OS (e.g. SB).

2.5.3.3.1 Problem description

The requirement REQ-TrainLoc-5 in [X2R3D42] states the following:

*When receiving a position report from a train **in FS/OS mode** where the Train Integrity is confirmed by external device, then the L3 Trackside shall update the Confirmed Rear End for this train from the information in that position report.*

According to this requirement the CRE is never established until the train switches to mode OS or FS. Thus, by definition, there is also no Train Location until the train switches to mode OS or FS. This restriction is not necessary as the train (according to CR940) is able to report a confirmed train integrity after having received the acknowledgement of the Train Data also for example in mode SB.

2.5.3.3.2 Proposal

Change the requirement REQ-TrainLoc-5 to also allow the update of the CRE as soon as the train reports a confirmed train integrity.

2.5.3.4 Trackside Train Detection: REQ-TTD-3 too restrictive

2.5.3.4.1 Problem description

REQ-TTD-3 states: *For a system using TTD, if the min Safe Rear End reported by a train is located in a clear TTD section while the max Safe Rear End is in an occupied*

TTD, then the L3 Trackside shall clear the Track Status for this train inside this clear TTD section.

In the rationale the following reason is provided:

TTD information can be used to improve performance of the system, but this should not result in a <u>train being removed from the Track State view</u> of the Area of Control

2.5.3.4.2 Example 1

Let us assume the following initial situation:

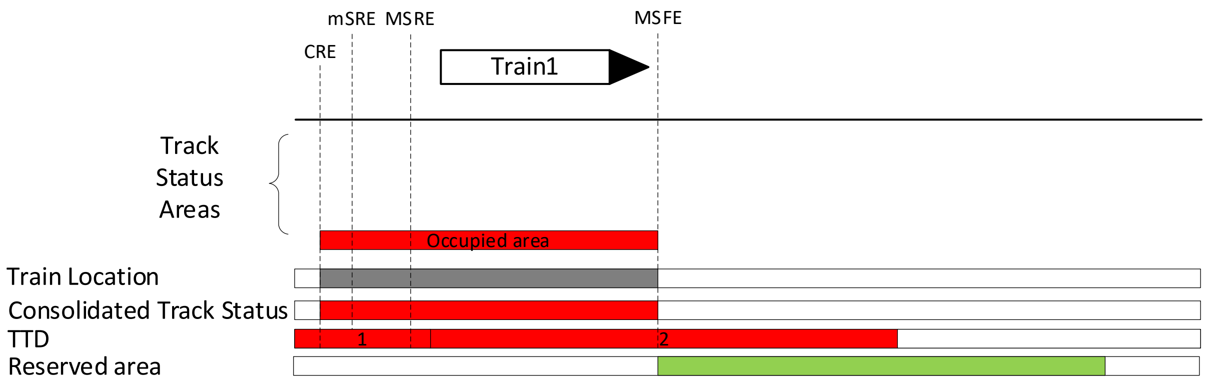

Figure 9: REQ-TTD-3 Too Restrictive – Example 1 Step 1

Now the TTD1 becomes 'Clear'. According to REQ-TTD-3, the Track Status within TTD-1 is not cleared yet.

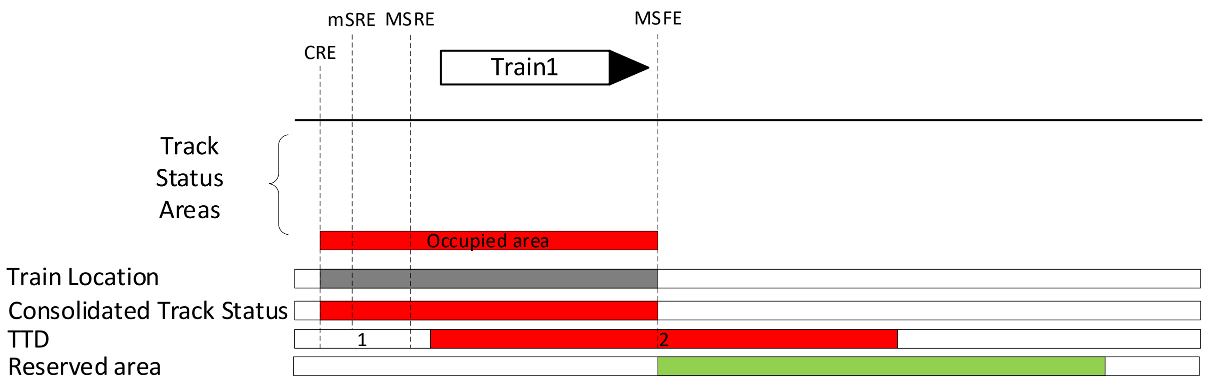

Figure 10: REQ-TTD-3 Too Restrictive – Example 1 Step 2

But in this situation, there is no risk that the train is being removed from the Track State point of view as the Track Status Area of the train already extends up to the MSFE of Train1.

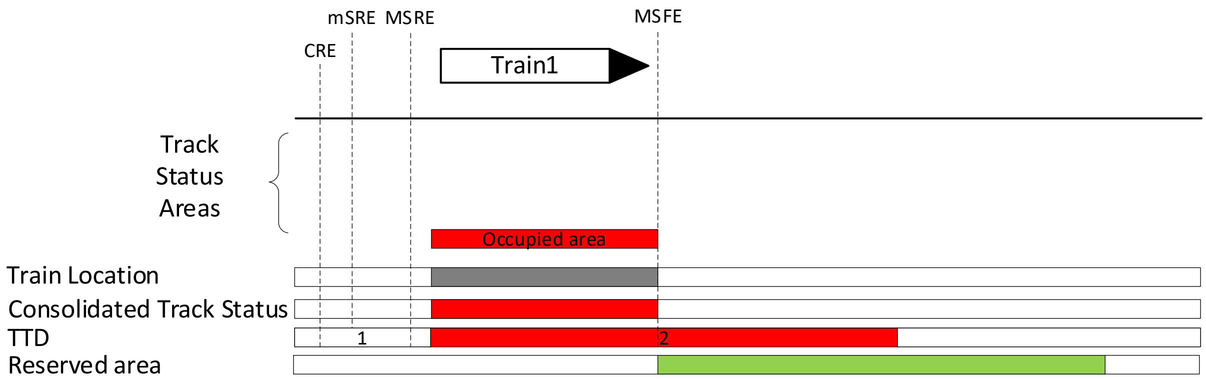

Figure 11: REQ-TTD-3 Too Restrictive – Example 1 Step 3

Therefore, it is possible to clear the Track Status Area when the TTD1 becomes 'Clear'.

2.5.3.4.3 Example 2

Let us assume the following initial situation in which the train has physically already left TTD1 but neither a position report has been received indicating that the train is already located on TTD2 nor TTD1 is cleared yet.

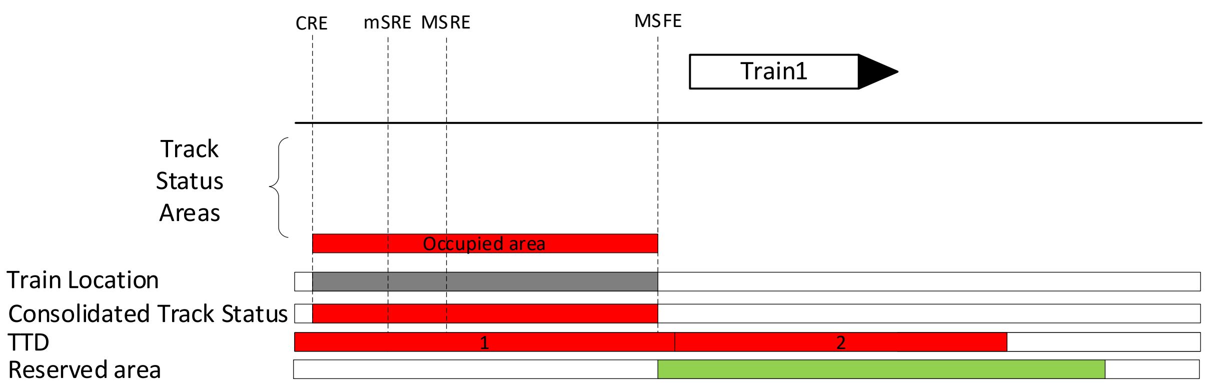

Figure 12: REQ-TTD-3 Too Restrictive – Example 2 Step 1

When the TTD1 now becomes 'Cleared', then according to REQ-TTD-3 the Track Status Area is not updated to avoid that the train is removed from Track State view of the Area of Control.

Figure 13: REQ-TTD-3 Too Restrictive – Example 2 Step 2

However, in this situation it is known (due to the Reserved area) that the train has moved towards TTD2 and thus the Track Status Area can be shifted onto TTD2. Then there is no need of a Track Status Area extending to TTD1 anymore.

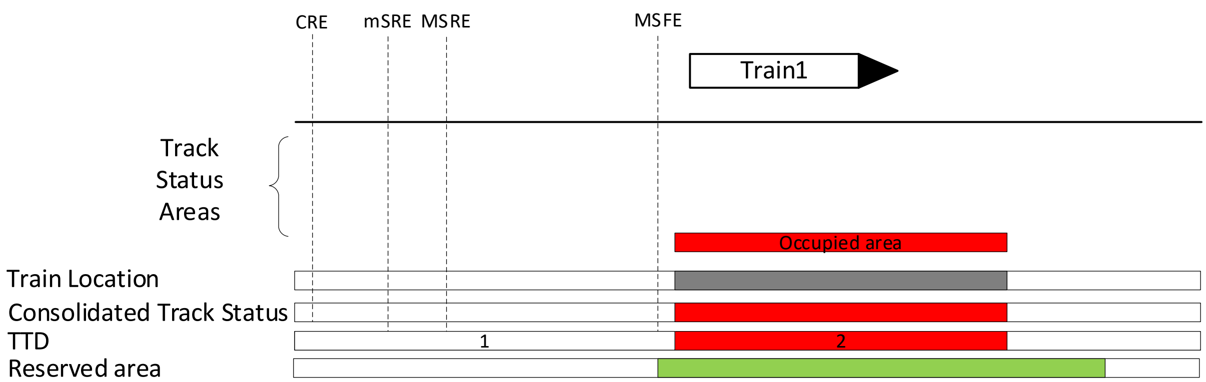

Figure 14: REQ-TTD-3 Too Restrictive – Example 2 Step 3

2.5.3.4.4 Proposal

The Track Status for a train inside a TTD that becomes ‘Clear’ can be always cleared independently whether the Track Status does not extend to the next TTD. When the Track Status Area of the train does not extend up to the next TTD yet or does not cover the whole train length then the Track Status Area needs to be shifted, resp. extended considering the Reserved Area (if any) to avoid that the train is removed from the Track State view of the Area of Control.

Note: Otherwise the behaviour of L3TS is worse than the behaviour of an L2 Trackside without FVB/Moving Block in such case.

3 Task 4.6 Technical Demonstrator 2 for Low Traffic

3.1 Objective

The purpose of this task is to demonstrate that the Level 3 principles applied to the Moving Block system with Fixed Virtual Blocks (FVBs) on a single inter-station Trackside Train Detection system (TTD), developed as part of X2Rail-3 WP4, can be implemented on target hardware according to engineering rules relating to low traffic.

3.2 Architecture and Environment

The Technical Demonstrator has been implemented on ETCS Trackside hardware covering the functionality of the STS L3 Radio Block Centre, which also computes and manages L3-specific path information (e.g. FVB status, mainline availability).

A simulated L2 Interlocking manages conventional interlocking information (e.g. information from field objects, including TTDs within stations and the inter-station TTD) and interfaces with this L3 Trackside.

The ETCS Trackside has implemented the relevant elements of the System Specification and has been configured in accordance with the Engineering Rules.

This architecture has been set up in a laboratory system, with the following composition and functional role:

A. Trackside, which is composed by:
   - STS software, implementing the ERTMS/ETCS Trackside based on X2Rail-3 deliverable D4.2 (L3 Trackside). Functions implemented are those of a “L3 RBC” (i.e. conventional RBC functions plus additional management of L3-specific path information). “L3-specific path information” are FVB status evolution by combining Position Reports/Train Integrity information received from the on-board with the TTD status received from a conventional IXL, and the availability of the line based on the state of its FVBs. This software also includes interface with conventional IXL, with the L3 Trackside Operator Terminal and with the on-board. All the interfaced subsystems are simulated.
   - Balises: ERTMS/ETCS balise database included within the L3 Trackside line configuration data.
   - IXL: ERTMS/ETCS L2-based Italian IXL simulator transmitting TTD status (both of station TTDs and of the inter-station TTD) and line direction to the RBC, as well as the status of any other physical or logical in-station object.

B. Train: ERTMS/ETCS L2 on-board simulator transmitting Train Integrity information according to the UNISIG CR940.

The Test environment implementing this system has the following composition:

a) Operator desk with monitors showing the Line and the Train display Panels and a few basic commands to the RBC, such as RBC Initialisation, and the L3 commands deemed necessary for the L3 scenarios implemented.
b) L3 Trackside target, which is the hardware platform hosting software of the L3 Trackside.
c) GTB (Gateway Terra Bordo): software “gateway” providing information transfer from the on-board to the IXL simulator. This gateway, configured with the same line database of the RBC, receives train position information from the on-board simulator and provides the IXL simulator with the occupied TTDs associated with this position.
d) On-board simulator: software interface from which it is possible to monitor communication with the RBC (communication status, message exchange) and to set several Position Report parameters and degraded conditions such as loss of communication and loss of integrity.
e) IXL simulator: software interface from which it is possible to set station path and line direction. This simulator interfaces with the GTB and with the RBC.

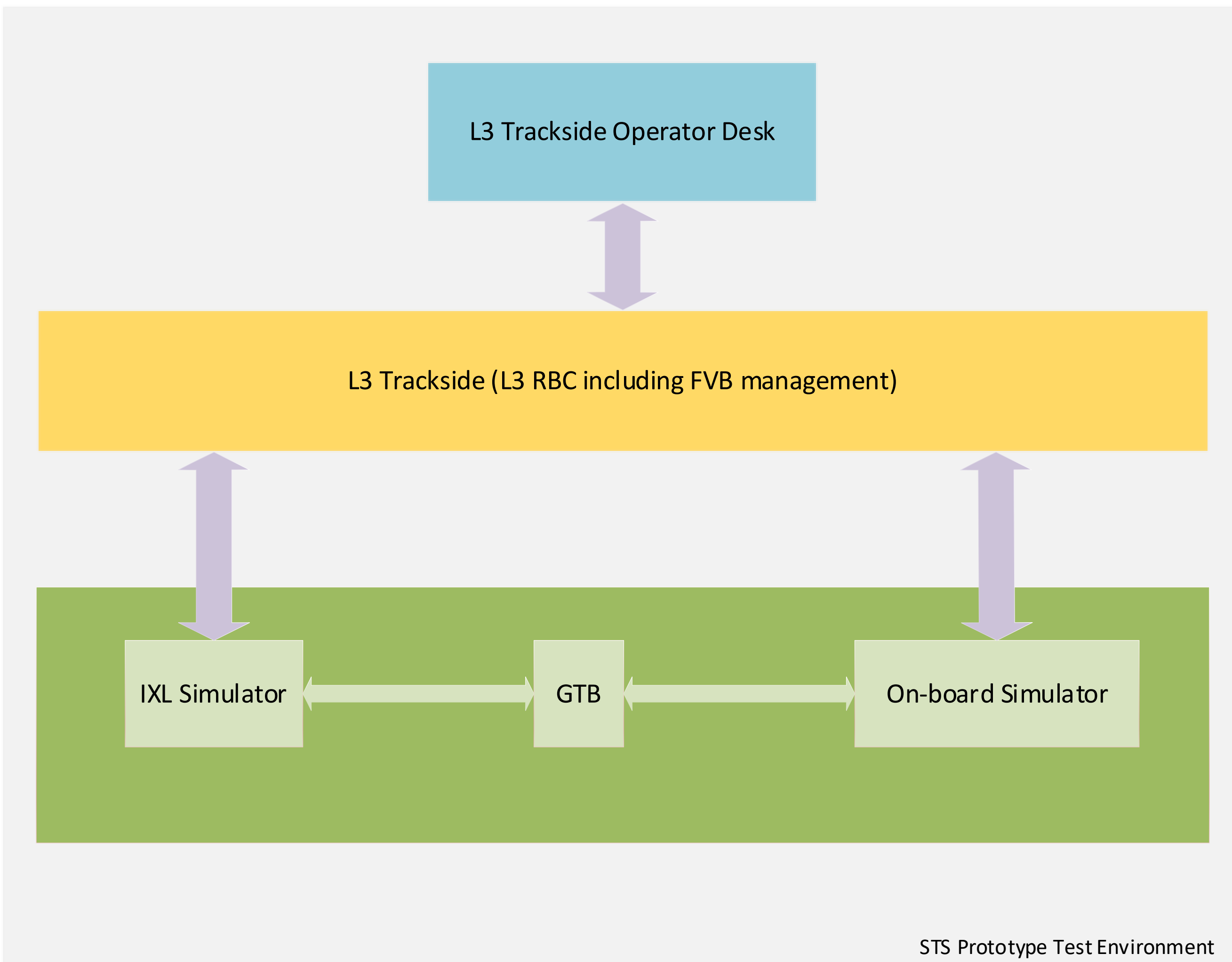

Figure 15: Low Traffic Demonstrator Architecture

3.3 Demonstrated Scenarios

The tests represent operational scenarios to demonstrate the ability of the current specifications to support normal as well as degraded operation.

The following scenarios/functionalities have been tested:

1. Normal Train Movement: one train following another train, both trains with Train Integrity Confirmed by external device.
2. Start of Mission: train performing Start of Mission and sending Train Integrity information to the L3 Trackside.
3. End of Mission: evolution of the FVBs where a train is performing End of Mission.
4. Loss of train integrity and recovery: reporting integer train losing and subsequently regaining integrity information.
5. Loss of communications and recovery: reporting integer train losing and subsequently regaining communication with the L3 Trackside.
6. SR Movement: a train performs a SoM with position unknown and the L3 Trackside provides a SR Authorisation based on the approximate location of the train without a valid location.
7. Change of direction: a train performs a new SoM with different cabin and moves in the opposite direction to the previous movement.
8. Sweeping: one reporting integer train following another one having lost integrity. The chasing train is authorised to sweep the FVBs left unknown by the preceding one.
9. TTDs: in all the above scenarios TTD status (received form the IXL) is taken into account by the L3 Trackside to determine the state of the FVBs in stations, together with the position information coming from the train via Position Report. The state of the FVBs in line does not depend from the state of the line TTD when at least a communicating train is located in the line.

3.4 Dissemination

A practical demonstration has taken place in the Hitachi laboratory in Genoa to give an overview of the STS demonstrator described at section 3.2. A long test has been executed, during which all the functionalities declared implemented were shown. A presentation was also held in parallel with the execution of the long test, so as to introduce each relevant situation before it took place during the demonstration. The HMI installation provided several views to visualize different system aspects and to facilitate verification of the behaviour. The track, the trains (represented by an icon reporting the train number in its inside), the extent of the Movement Authority and some other details have been animated and displayed in one view. The DMI of the OBU simulator and the interface with the IXL Simulator have also been shown.

A video, reproducing in a simulated environment the same long scenario executed in the laboratory, has also been used to support the same demonstration remotely, and also to show the LossComms scenario, whose execution on target has been avoided since complicated by technical problems in the hybrid environment set up (Simulated on-board with real L3 Trackside).

3.5 Results and Conclusions

3.5.1 Railway Type

As for the specific trackside application modelled, the ERTMS L2-based “Novara-Padova” Line has been selected for this prototype.

This Italian line is included within the European CNC (Core Network Corridor) Project designed from Lisbon to Kiev (CNC V), and intersecting Italy for about 1000km, from Turin to Venice, as shown within Figure 16 (the green path between red indicators).

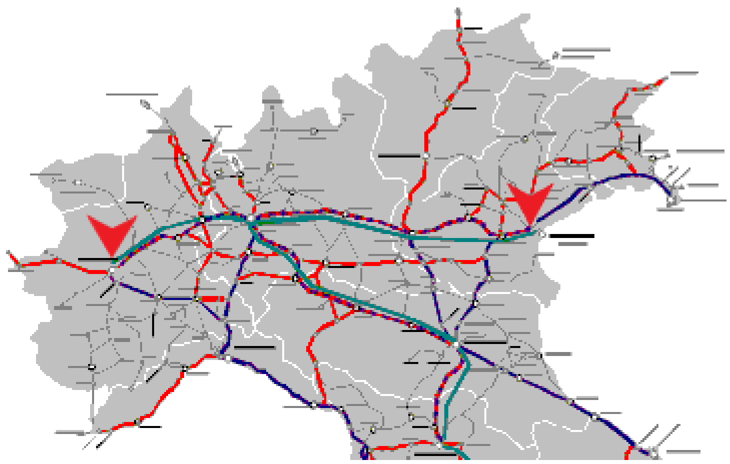

Figure 16: Novara-Padova area

A migration from the pre-existent SCTM (Sistema di Controllo Marcia Treno) National System to the pure BL3 R2 ERTMS/ETCS L2 system has been planned for the Italian part of this Corridor, throughout the progressive activation planned for each composing branch, including “Novara-Padova”.

The application “Novara-Padova” is double track and will have TTDs and virtual signals in the main line. It includes about 20 stations, among which there are some relevant nodes such as those located in Milano Greco and Verona. These nodes provide connection with the regional railways, for which the national signalling system (SCMT) will be maintained. Both passenger and freight trains are admitted, and the maximum speed allowed is 160 km/h.

The portion of this line from Trecate to Magenta station has been selected for being re-engineered according to X2Rail-3 Moving Block Specification, as well as the L2 Trackside application software has been replaced with the one developed within the TD2.3, and based on X2Rail-3 Moving Block Specification as well. Stations have not been re-engineered (except for the arrival/departure zone) since not relevant for the functionalities implemented for this prototype. The selected portion of line has no points and no shunting areas.

3.5.2 System Type

The trackside system type designed is basically a Moving Block with Fixed Virtual Block system type without TTDs within the main line. A single axle counter between the adjacent stations of Trecate and Magenta has been maintained. This specific configuration is due to the following considerations:

- On one side, there was the objective of reducing infrastructure costs, whereas the pre-existing infrastructure characterising the line selected for prototype includes TTDs in the stations and this was to be taken into account as well, especially considering a future in-site testing activity. The best trade-off has been not to change the pre-existing configuration within stations, but this has implied that an inter-station axle counter should be kept as the minimum equipment required to preserve the conventional detection of train arrival and departure in/from each station as well.
- FVBs have been deemed necessary for being associated with in-field markers, that may be necessary to define the boundaries of some specific areas.
- Both Low Traffic and Freight services may also benefit from FVBs by achieving the maximum capacity possible according to their characteristics without requiring Full Moving Block, since an ETCS Level 3 Moving Block with Fixed Virtual Block system can be properly engineered to provide the same capacity of a Full Moving Block system.The line from Trecate to Magenta Station has been re-engineered with FVBs of about 700m each. There were no line elements that could condition the length of the FVBs, therefore the chosen length has been based on the average length of the admitted trains. Passenger trains are always shorter (no more than 450m long) while freight trains are always longer (no more than 1000m long) than this medium value, therefore in both cases this length provides more separation between trains running in the same direction than that provided only by using their CRE, with no need for any additional safety margin to be implemented for this application. Each FVB is delimited by virtual markers, visible to the Operator on his Display Panel. A view of the Operator Display Panel is shown in Figure 17:

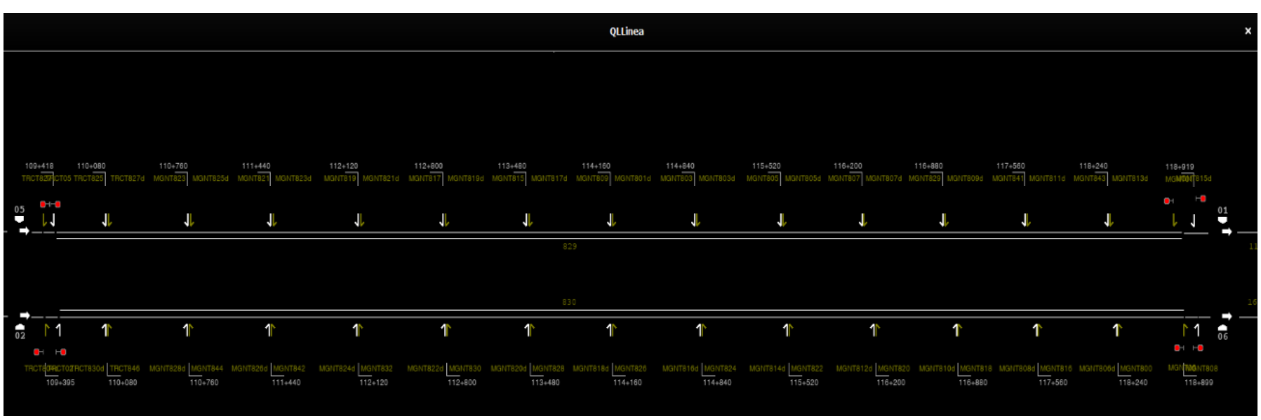

Figure 17: Sample prototype view from the Dispatcher Control Panel

3.5.3 Results

X2Rail-5 STS prototype has tested X2Rail-3 prototype on target and fixed the bugs experienced. several degraded situations have been tested both individually and in a combined manner so as to improve software reliability and safety. In addition, SR movement has been completed by implementing SoM from unknown position.

More schematically, the following functionalities were tested:

1. Initialisation of Trackside:

   Initial Conditions

   - Trackside Startup with no trains: all the FVBs of the line have unknown status, the L3 Trackside is not able to detect information from the IXL and the inter-station TTD state is set to the safe state (occupied).

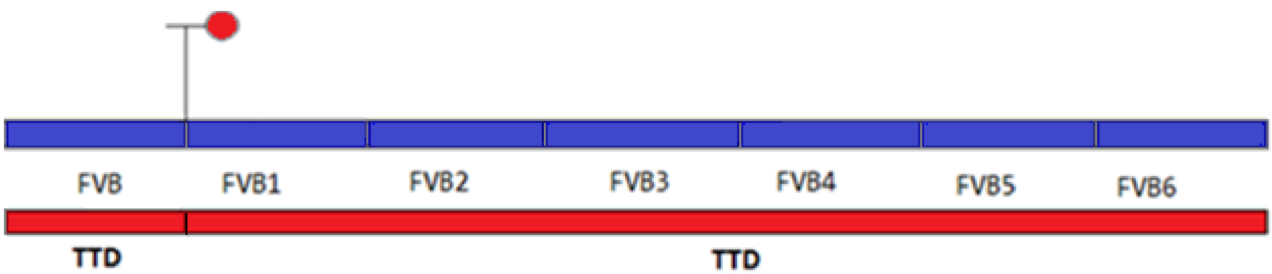

Figure 18: L3 Trackside detection before initialization

   Events

   - The RBC is able to detect information from the IXL and the inter-station TTD transitions to free. The Operator sends the Initialisation Command to the RBC with which confirms that the startup process is finished and the FVBs of the line transition to free.

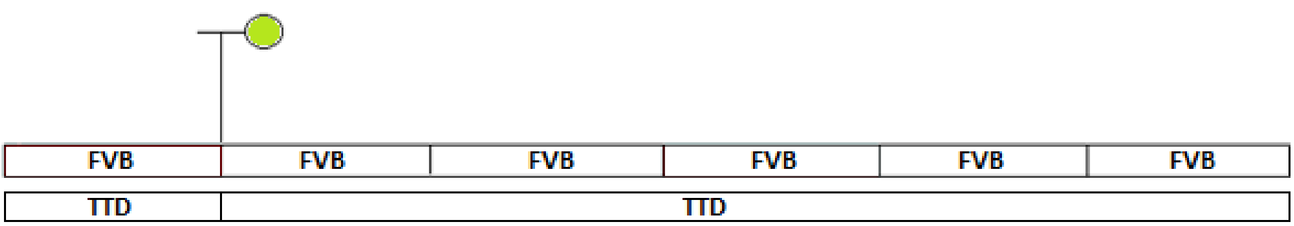

Figure 19: L3 Trackside detection after initialization (no trains)

2. Start of Mission from known position:

   Initial Conditions

   - A communicating train, Train 1, equipped with TIMS (separate system external to the ETCS On-board), is located in SB mode on the departure TTD of a station

Events

- The FVBs associated with the Station TTD occupied by Train 1 become unknown as soon as this occupation is detected, and until the RBC receives a PR reporting that the train is integer, after the acknowledgment of the Validated Train Data Message.

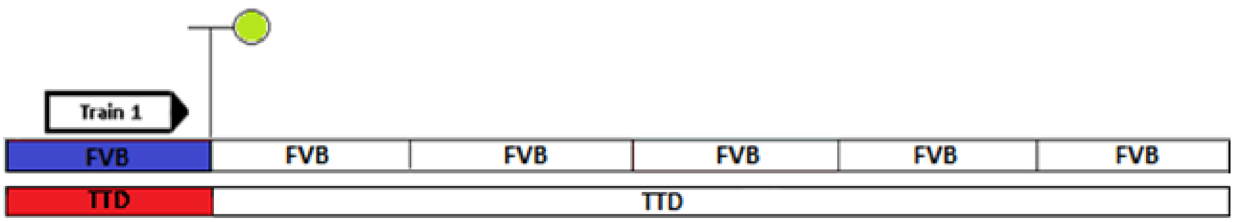

Figure 20: Train 1 with known position on departure TTD (initial step).

- The L3 Trackside acknowledges the Validated Train data Message received from the on-board.
- Train 1 has sends a PR including confirmed Train Integrity information and the L3 Trackside regards it integer (as a consequence of this event, the FVBs associated with the Station TTD and also relevant for the train position computed become occupied).

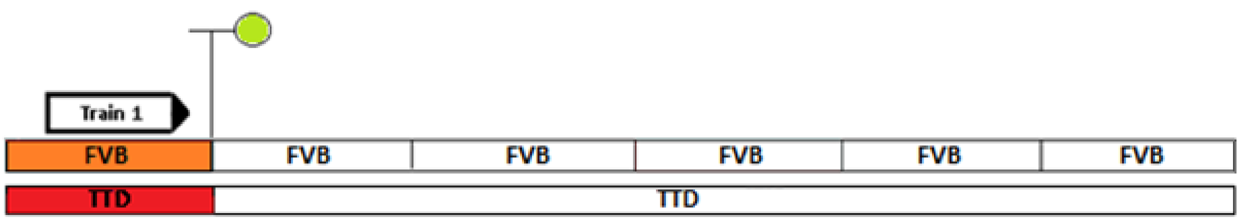

Figure 21: Train 1 with known position on departure TTD (final step)

3. First MA Assignment:

Initial Conditions

- See Figure 21

Events

- On receiving the Start Request Message [Msg132] from Train 1, the L3 Trackside activates the assignment of the Movement Authority process and sends a Movement Authority to the train, including linking information.
- The L3 Trackside shows the Movement Authority on its light panel.

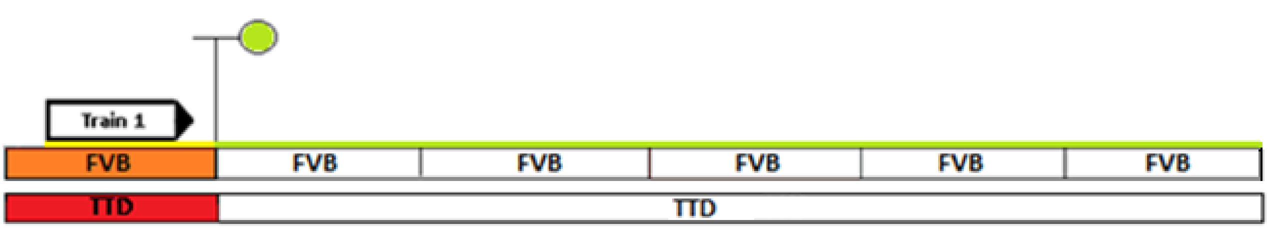

Figure 22: Line reserved to Train 1

4. Normal Train Tracking (one train):

Initial Conditions

- See Figure 22

Events

- The L3 Trackside localises the Train front end of Train 1 on the first FVB of the line, which becomes not available. The state of the line TTD transitions to occupied.

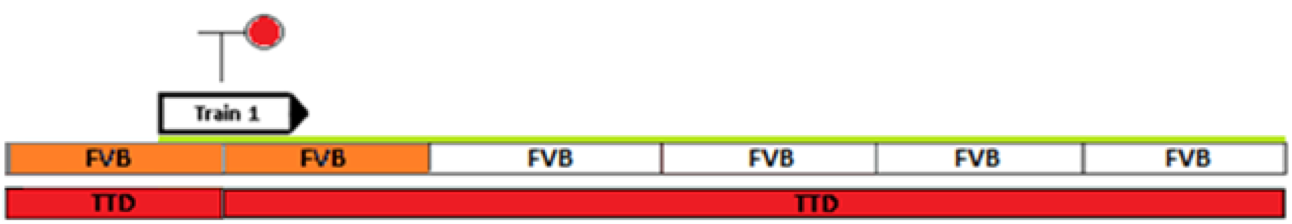

Figure 23: Train 1 occupies the line

- The L3 Trackside updates the state of the line FVBs as the train moves along the line.
- As soon as L3 Trackside detects that the first FVB of the line transitions from occupied to free, considers the line again available to be run in the same direction as Train 1 (project-specific choice).

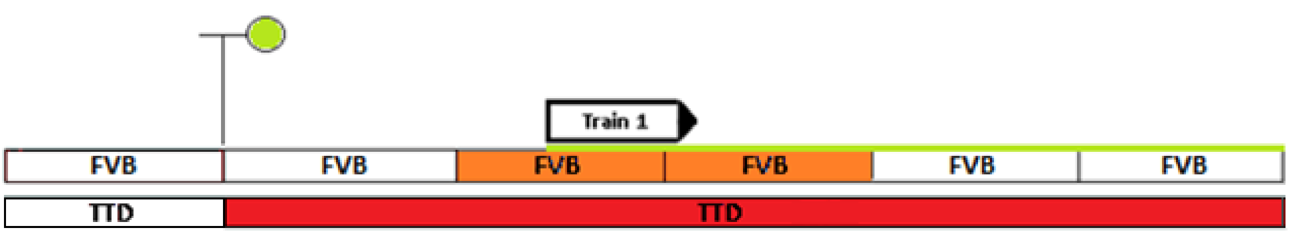

Figure 24: Line available for a chasing train

5. Normal Train Tracking (two trains):

Initial Conditions

- Train 1 moves along the line according to Figure 24.
- A communicating train, Train 2, with Train integrity confirmed by a TIMS (separate system external to the ETCS On-board), performs SoM and is localised in rear of Train1.

Events

On receiving the Start Request Message [Msg132] from Train 2, the L3 Trackside evaluates the status of the Fixed Virtual Blocks of the line and sends a Movement

Authority to Train 2 up to the starting signal of the Fixed Virtual Block occupied by the Confirmed Rear End of Train 1.

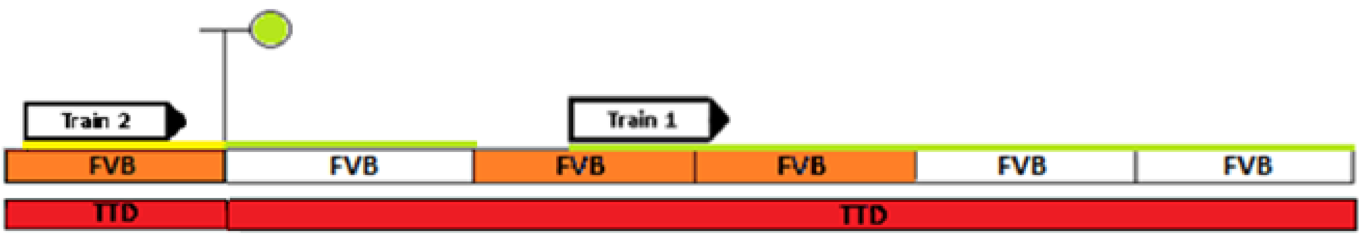

Figure 25: Line reserved to Train 2

- As Train 1 moves, the L3 Trackside automatically extends the Movement Authority to Train 2 up to the starting marker board of the FVB currently occupied by the Confirmed Rear End of Train 1.

6. Loss of Comms:

Initial Conditions

- Train 1 moves along the line according to Figure 24.

Events

- A loss of communication with the train is detected from the L3 Trackside, and all the FVBs from the one including its CRE and the one ending at the End of Authority of its MA transitions to the unknown state.

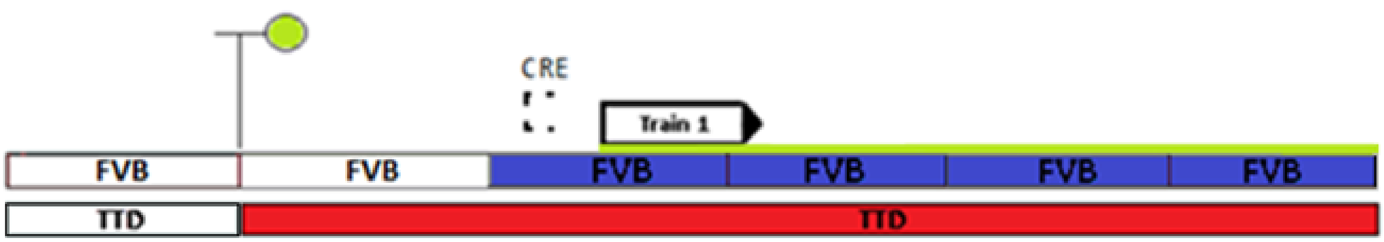

Figure 26: FVB Status due to Loss of Comms

- This state remains as Train 1 moves.

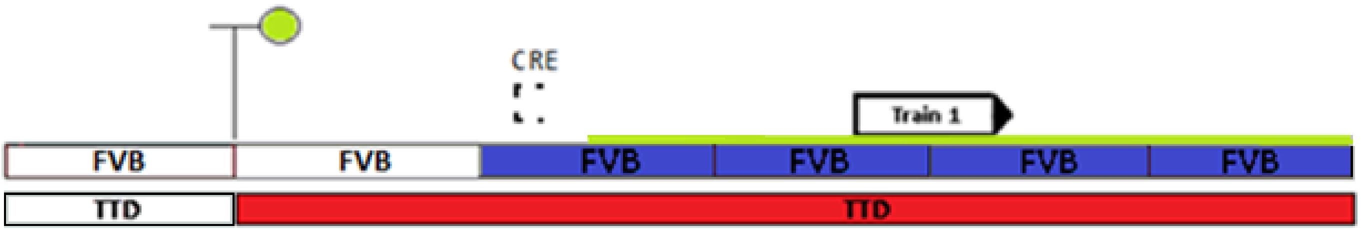

Figure 27: FVB Status due to Loss of Comms remains

- Train 1 regains communications with the RBC and sends a new Position Report with train integrity information. The state of the unknown FVBs transitions to free or to occupied depending on the currently reported position.

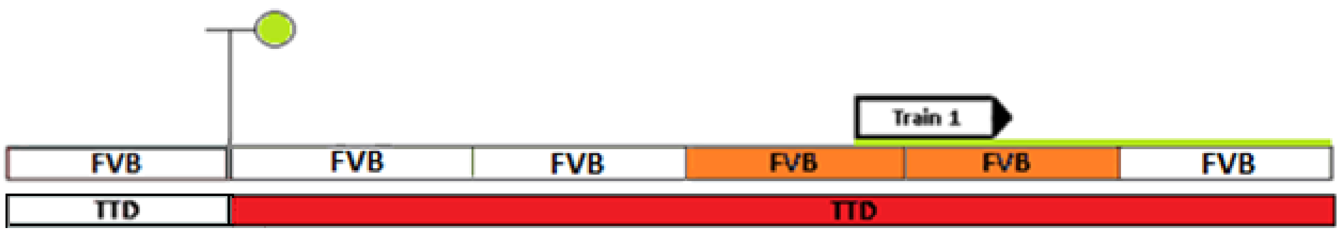

Figure 28: FVB Status updated after Train 1 has regained communications.

7. Loss of Integrity:

Initial Conditions

- Train 1 moves along the line according to Figure 24.

Events

- Train 1 sends a PR with information of loss integrity.
- The L3 Trackside receives the PR with information of loss integrity and sets to Unknown the Fixed Virtual Blocks from the one including the last CRE computed to the one including the current Max Safe Front End computed.

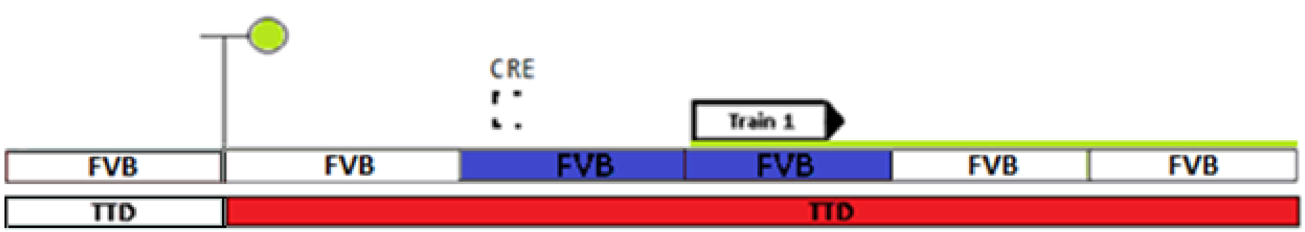

Figure 29: Train 1 loses integrity

- As the train moves according to its MA, the L3 Trackside sets to Unknown each FVB on which its Max Safe Front End is detected, based on the PR information.

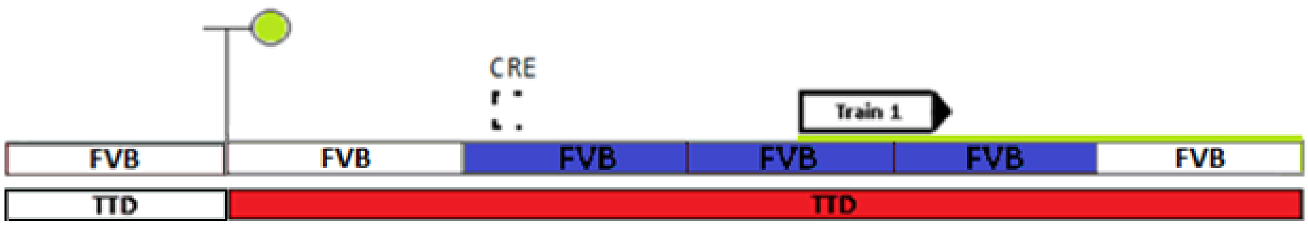

Figure 30: FVB status while non-integer Train 1 keeps on running.

- Train1 reports the integrity confirmed again.
- The L3 Trackside cleans up the Fixed Virtual Blocks in rear of the one including the current CRE and sets to the occupied state all the FVBs currently detected occupied based on the current PR and integrity information received

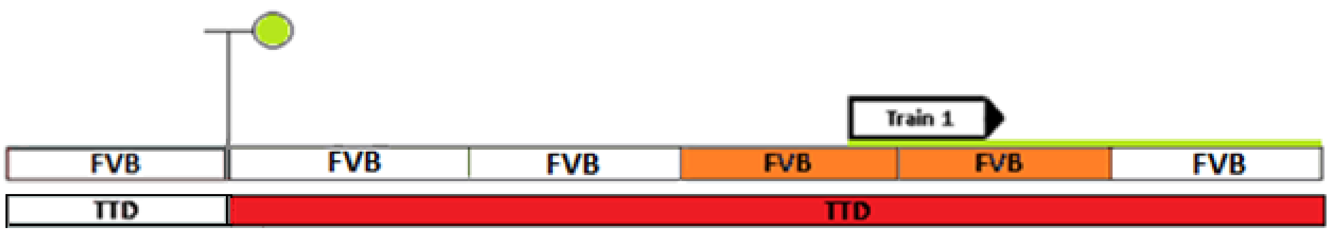

Figure 31: Again integer Train1 running in the line

8. Sweeping:

Initial Conditions

- Train 1 and Train 2 move along the line according to Figure 25

Events:

- Train 1 integrity information is no longer available
- On receiving an MA request message from Train 2, the L3 Trackside extends the Movement Authority to Train 2 up to the current min safe rear end of Train 1, with an on-sight profile extended from the starting signal of the FVB including the last reported CRE of Train 1 to the starting signal of the one including the current min safe rear end of Train1.

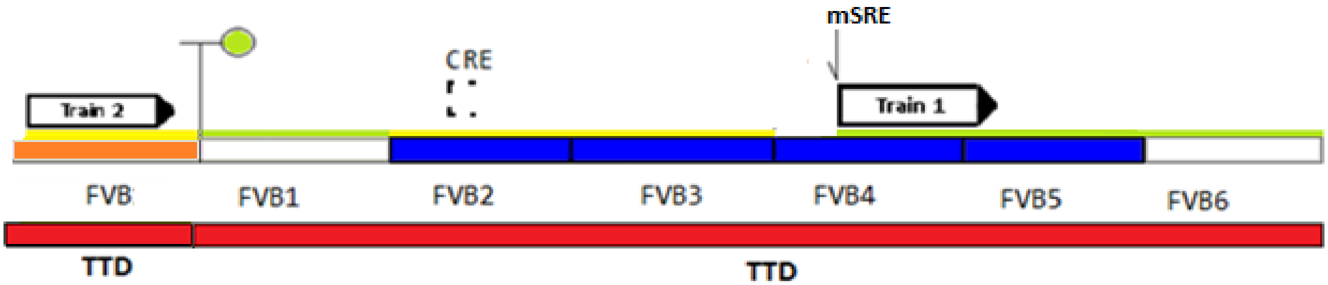

Figure 32: Sweeping MA issued to Train 2

- The Unknown FVBs included in the MA for Train 2 will become clear after the passage of the train with Train Integrity confirmed

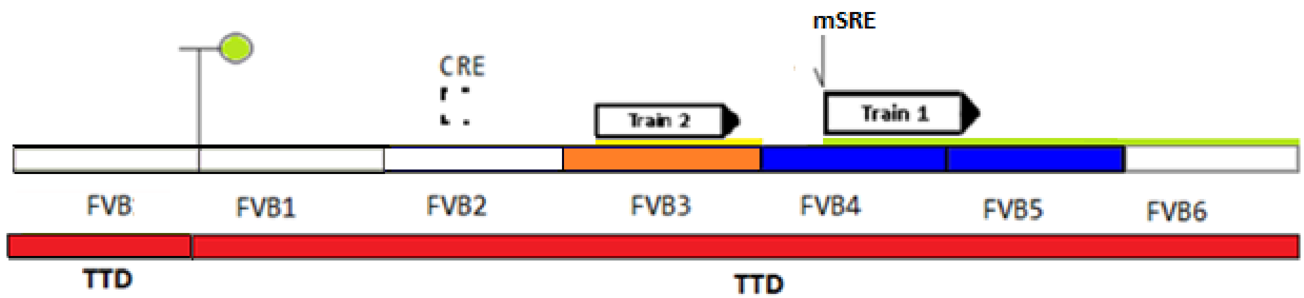

Figure 33:Train 2 sweeping the line

9. SoM with unknow position and SR Authorisation assignment:

Initial Conditions

- Train 1 is located in SB mode on the departure TTD of the station, which becomes occupied.

Events:

- Train 1, in SB mode, sends the L3 Trackside a SoM position report with unknown position.
- L3 Trackside shows the messagge "Request for Approximation: START to INSERT" to alert the Dispatcher he can start the procedure to approximate the train.
- From the HMI, the dispatcher selects the train requiring the approximate procedure, to associate the train with the procedure itself.
- Based on localisation information received from the driver (operational procedure), and on the train length information received within validated train data forwarded by the L3 Trackside, the dispatcher selects both the marker board in front of the train and the FVBs which are supposed to be occupied by the train. The selected FVBs transitions from clear to unknown

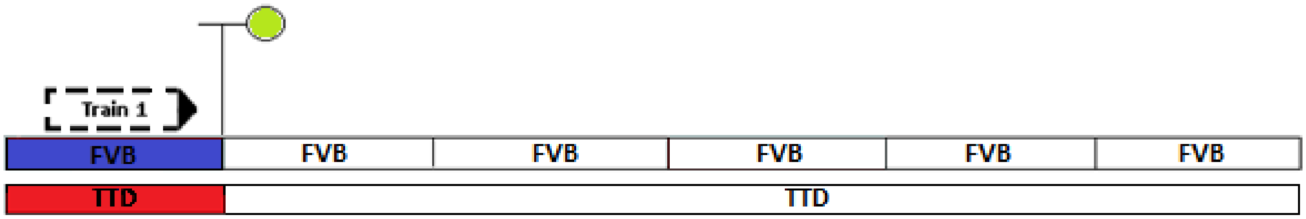

Figure 34:Train with approximate position assigned and ready for the SR authorisation

- The L3 trackside considers the approximation procedure successfully completed for the train.
- On receiving the Ma request message from Train 1, the L3 Trackside activates the calculation of the SR Authorization.
- The L3 Trackside assigns the SR authorization to Train 1, that includes both the selected FVBs under the train and those, beyond the signal in front of the train, allowing the captation of at least two double BGs.

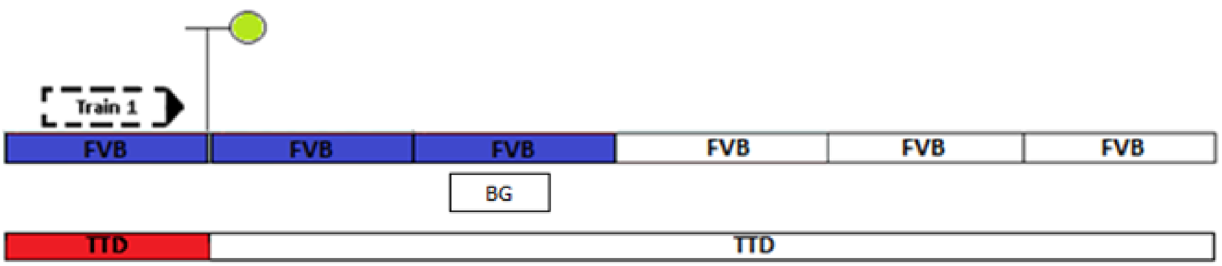

Figure 35:Train with SR Authorisation assigned

- Train 1 receives the SR Authorization [Msg 2] with packet 63 that includes all balise groups belonging to the FVBs of the SR Authorization.
- Train 1 moves along the line in SR mode within the path of the SR Authorisation received until the L3 Trackside receives a valid PR with known position.
- On receiving a PR with a known position from Train 1, the L3 Trackside localises the train and starts computing the Movement Authority for the train according to the line conditions, analogously to the previous scenarios where a train with known positions is provided with an Movement Authority to run in the line.

Observation: The test above-described is exactly what happens in the absence of a latency timer for undue occupation, or in any situation which prevent latency timer to be activated (for example, latency timer will not get active if there is at least another localised train on the same TTD occupied by the non localised one). Tests with active latency timer have showed that requirement REQ-TTD-7 (faulty TTD) may have an impact on the FVB status of the TTDs occupied from a train with unknown position. In fact, when a SoM with unknown position starts, the TTD(s) occupied by the involved train cannot be associated with the train itself until the operator has selected its approximate position. Since REQ-TTD-7 has been implemented with a timer of 20s (about the time of two position reports) and any operational procedure takes more time, the unknown area under the train is created before and independently from the approximate position assignment. Our judgement about this behaviour is that it is both safe and correct, since this Start of Mission cannot be distinguished from a possible faulty occupation in its early phase (e.g. until the approximate position assignment ends). Of course, the assignment of the approximate position, which is finalised by the operator by selecting the FVB(s) deemed involved in the train localisation, also implies the creation of an unknown area over the selected FVBs, in compliance with both guidance of REQ-TrackStatus-2 and REQ-MovSR-5. In conclusion, when it comes to define the unknown area of the FVBs associated with a TTD occupied from a non-localised train requesting approximate procedure, REQ-TTD-7 overlaps and anticipates what should have happened because of REQ-TrackStatus-2 and REQ-MovSR-5, though not replacing them. FVBs associated with free TTDs included in the path reserved for the SR Authorisation will become unknown only after the SR Authorisation has been assigned.

10. End of Mission:

Initial Conditions

- Train 1 moves along the line according to Figure 24.

Events

- The train performs End of Mission within the line. The state of the FVBs on which the train is located transitions from occupied to unknown

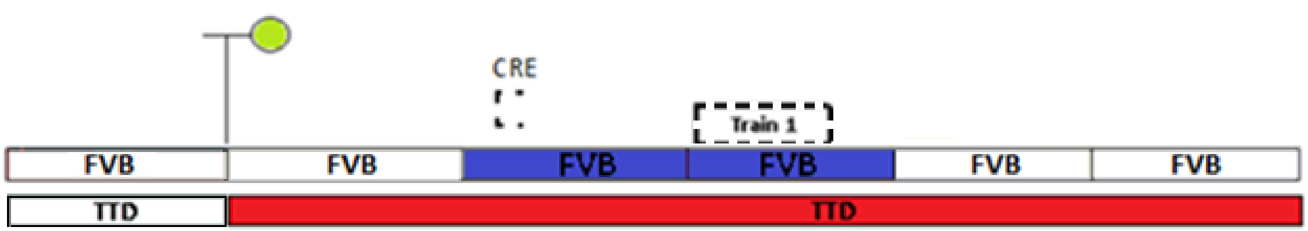

Figure 36:Train performing EoM

- This state of the FVB remains until swept from the same train after a new SoM or cleaned-up by means of a command from the operator.

11. Change of Orientation:

Initial Conditions

- An integer train with two cabins has entered a station and performed End of Mission.

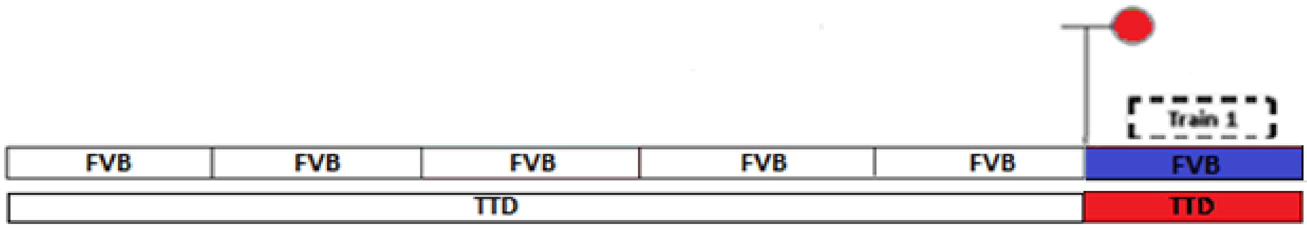

Figure 37:Train performing EoM at the arrival station.

Events

- The same train needs to start a new Mission in the opposite direction (towards the station from which he had come).
  The driver moves to the other cabin and turn it on. From the new active cabin, the train starts connecting to the L3 Trackside and performs a new SoM.

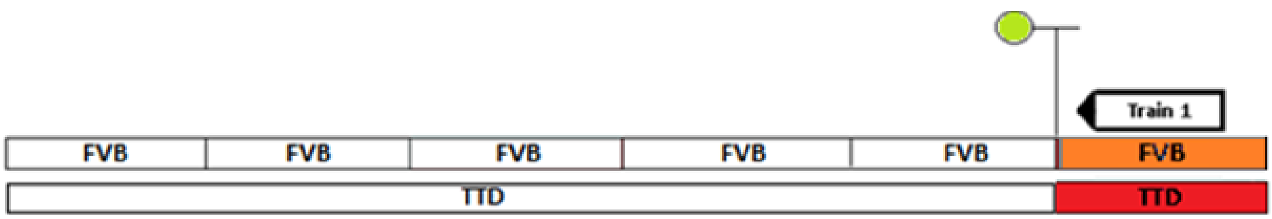

Figure 38:Train ready for departure after SoM from a new cabin.

From the performance perspective (basically line capacity and traffic fluidity), the engineering choices made within the X2Rail-3 deliverable D4.4 have been deemed valid also for this upgraded STS prototype, with no need to implement the most recent moving block concept that the CRE of the preceding train should represent the Danger Point for the following train. This because it has been estimated that this approach would not have led to any significant improvement within an FVB-based moving block system, which still remains the most convenient system choice for those lines, such as the low traffic ones, which have no particular needs in terms of capacity. Given the fact that the original portion of line selected from the “Novara-Padova” line has track sections long about 2000m, configuring FVBs of 700m has reduced the headway by around a third, with the same trains (type and length).

4 Task 4.7 Technical Demonstrator 3 for Urban/Suburban

4.1 Objective

The purpose of this task is to demonstrate that the principles for Level 3, for a Fixed Virtual Blocks with Trackside Train Detection system focus on the mainline, developed as part of X2Rail-3 WP4, can be implemented on target hardware and that the desired operation can be achieved. It is not planned to include refinements from X2Rail-5 WP4, unless there is a consolidated, fundamental change to be considered for a the urban/suburban traffic.

4.2 Demonstrated Scenarios

The tests represent operational scenarios to demonstrate the ability of the current specifications to support normal as well as degraded operation.

The following scenarios/functionalities will be tested:

1. Level transitions entry to L3: train in National level enters in L3 Area at the border
2. Level transitions exit from L3: train in L3 exits to National level at the border
3. Normal Train Movement: one train following another train, both trains with Train Integrity Confirmed by external device.
4. Start of Mission: train performing Start of Mission and sending Train Integrity information to the L3 Trackside, then train moves in Normal Movement.
5. End of Mission: evolution of the FVBs where a train is performing End of Mission
6. Change of direction: a train arrives at station and performs EoM. Then the train performs a SoM with the other cabin and moves in the opposite direction (pending on the test environment to check whether this is possible).
7. Loss of train integrity and recovery: two trains in normal movement, the forward train loses train integrity, as this train keeps moving its rear end is frozen and the MA of the chasing train does not progress. When Integrity is regained, Track Status is recovered and the MA of the chasing train is lengthened as the chased train releases the FVBs.
8. Loss of communications and recovery: two trains in normal movement, the forward train loses communications. The area where this train can be is protected and the MA of the chasing train is not lengthened until the chased train regains communications.
9. Sweeping: a train sweeps an Unknown area and recovers the track status.
10. TTDs: In all the above scenarios TTD status (received form the IXL) is considered by the L3 Trackside to determine the state of the FVBs of the line, together with the position information coming from the train via Position Report. In some scenarios the chasing train reports always TI lost so TTD are used to clear Unknown Track Status Areas.

4.3 Architecture and Environment

The Technical Demonstrator was implemented on ETCS Trackside hardware covering the functionality of a FVB system and the Radio Block Centre. The ETCS Trackside implement the relevant elements of the System Specification and was configured in accordance with the Engineering Rules.

Figure 39 indicates the architecture of the demonstrator.

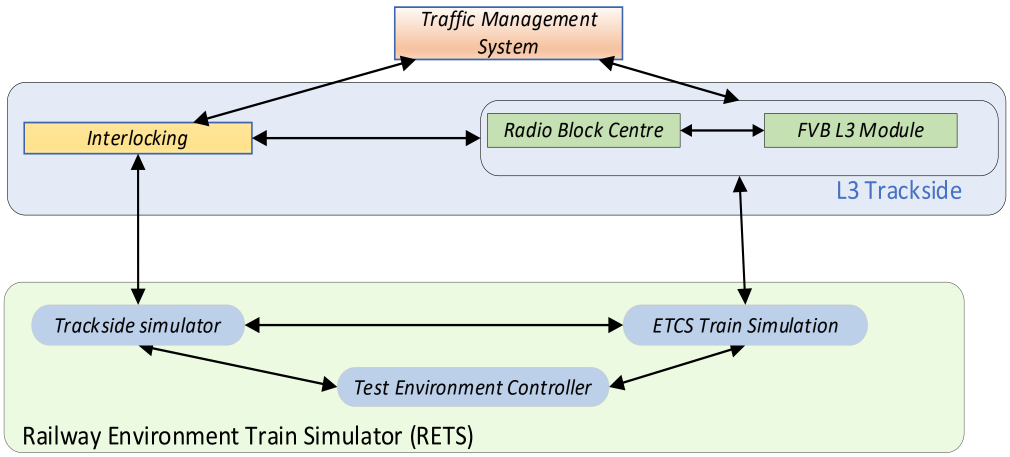

Figure 39: Urban/Suburban Demonstrator Architecture

- The L3 Trackside: will consist of Interlocking, RBC and L3 FVBs Module. They will be operated on target hardware platforms.
- The TMS will be allocated on the same platforms used in commercial projects. The TMS will provide the view of the system (trains, status of TTDs, FVBs, MAs, etc…).
- Train and track simulator: The Railway Environment Train Simulator (RETS) is in charge of simulate the train, provides ETCS On-board functionality (Baseline 3 [BL3 R2]), messages sent to the L3 Trackside and the possibility of trigger events to manage Train Integrity functionality or a loss of communications (such as Mute timer). RETS is also in charge of providing the status of the different elements of the trackside as balises, points or TTD state.

Figure 40 shows an annotated photograph of the Technical Demonstrator.

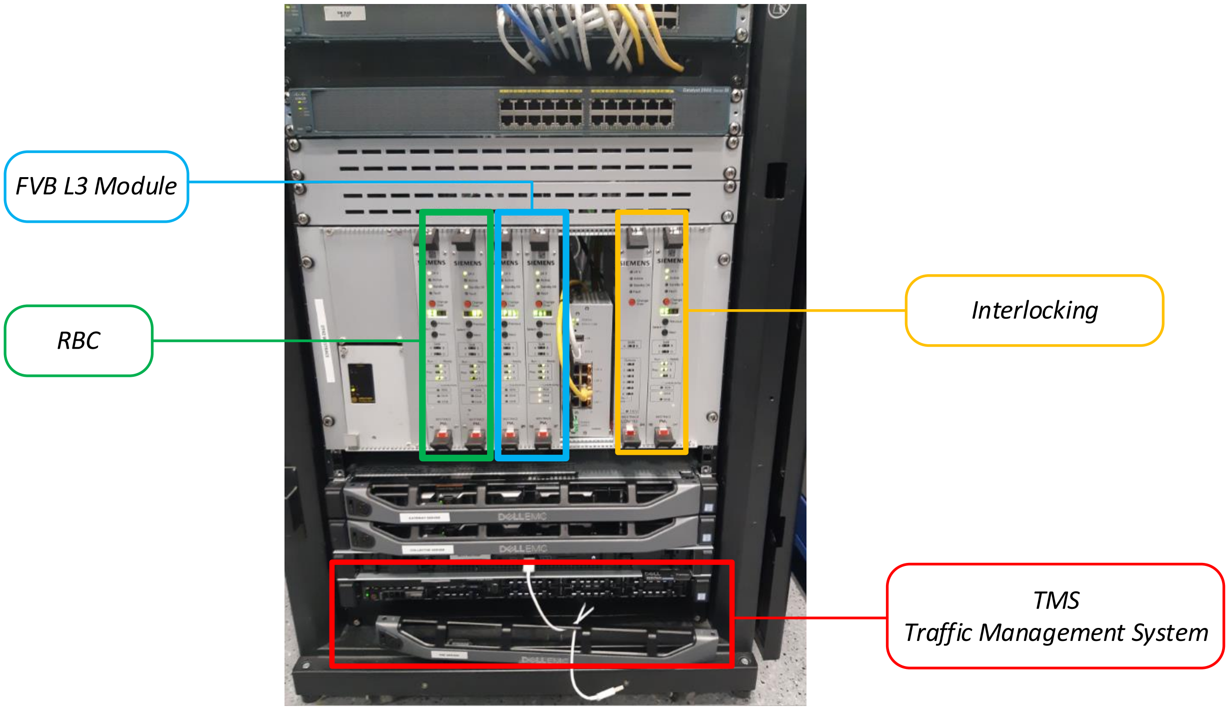

Figure 40: Annotated Photograph of Urban/Suburban Technical Demonstrator

4.4 Dissemination

SIEMENS has prepared a video to give an overview on the demonstrator, the test environment and the executed tests. In the video, the TMS provides a view to visualize different system aspects and to facilitate verification of the behaviour.

The track (TTDs and FVBs), the trains (represented by the running number), extent of the Movement Authority and some other details were animated and displayed. The concepts from the X2Rail-3 Moving Block System Specification such as Train Location or Track Status were dynamically updated and visualized following the specification.

The video was shown to WP members, with time for questions to be asked, and with the scenarios paused and re-played to provide further explanation and clarification.

4.5 Results and Conclusions

4.5.1 Railway Type

As for the specific trackside application modelled, the Network Rail ENIF line at Hitchin, UK was selected for this prototype as this line and the Moving Block Technical Demonstrator was also used for WP12 Integrated Technical Demonstrator.

The demonstrator was constructed using real data from an area of existing operational infrastructure in the UK. The red highlight in Figure 41 below shows the area of railway used.

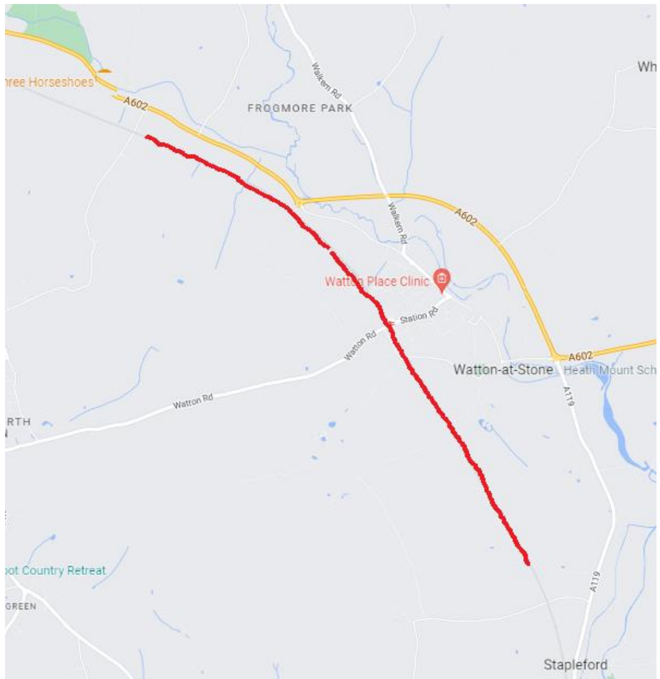

Figure 41: ENIF line in Hitchin

The area modelled is 10 Km in length with two tracks (Up & Down lines). For the prototype only one track was engineered. The original line is fitted with TTDs and light signals.

4.5.2 System Type

The system type is Fixed Virtual Blocks with Trackside Train Detection (FVB with TTD).

In order to engineer the line, most of the existing TTDs have been combined to create longer TTD sections. Each TTD, depending on its length, has been engineered with three or four FVBs, but the TTDs at borders where only one FVB was engineered per TTD. This allows to have two trains in one TTD in normal movement.

The line has an entry signal and an exit signal at level border locations. In order to allow Dispatcher to request paths for the trains, the current signals have been maintained.

Figure 42 below shows a sample of the prototype view of the Dispatcher control panel.

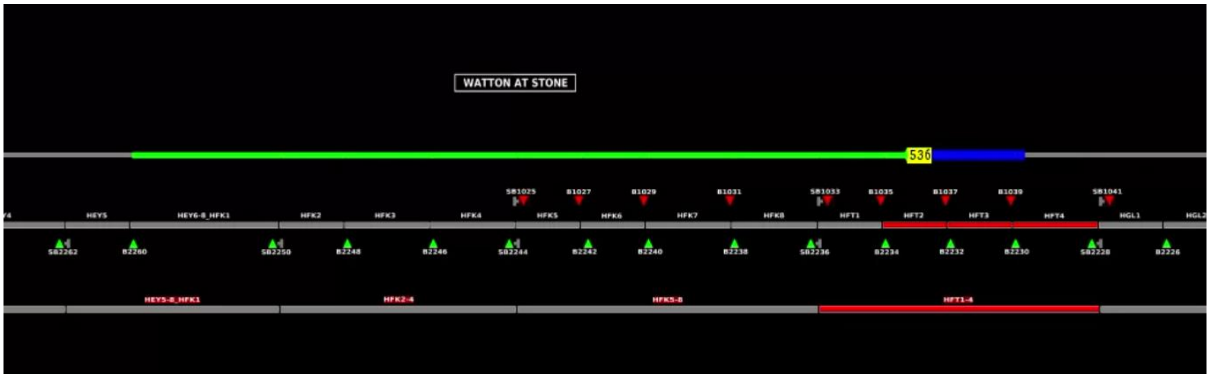

Figure 42: Prototype view from the Dispatcher control panel

4.5.3 Results

The following functionalities were tested:

12. Level transitions entry to L3:
    A train in NTC is on the approach to the L3 border, located at virtual signal. The state of the FVBs are initially Clear. The train establishes a communication session with the L3 Trackside and starts reporting a valid location with Train Integrity Confirmed by External device. The L3 sends an MA to the train before the train reaches the border. When the train reaches the L3 border, the first TTD in the L3 area becomes Occupied and the train reads the border balise group. In this test:
    - The train location is established for the first time when the train reports within the L3 Area and it is adjusted with Reported Train length
    - train location is adjusted when Train Integrity is confirmed by external device
    - FVB Track Status associated to the train is set from clear to Unk or Occupied depending on the Train integrity information received from the trains.
    - Level transitions exit from L3: train in L3 exits to National level at the border

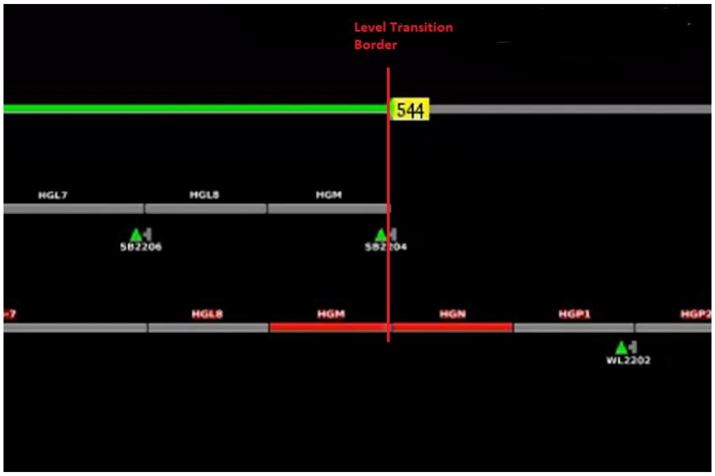

Figure 43: Level 3 entry

13. **Normal Train Movement:**
One train following another train, both trains with Train Integrity Confirmed by external device.
As soon as a FVB of the line becomes Clear in rear of the forward train (the FVB corresponding to the train occupation change its status as the train moves), the L3 Trackside extends the MA for the chasing train up to the end of the last clear FVB in rear of the FVB occupied by the CRE of the chased train.

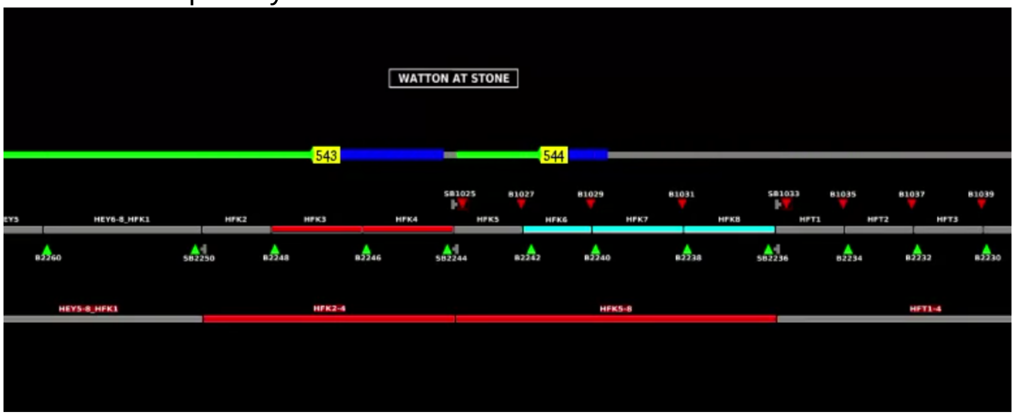

Figure 44: Normal Movement

14. **Change of direction at station:**

A train arrives at station and performs EoM. Then the train performs a SoM with the same train length with the other cabin and moves in the opposite direction. In this scenario several functionalities are tested:

- EoM:
  - the train when does EoM removes the remaning Reserved Area
  - the FVBs where the train is located change from Occupied to Unknown
  - L_TRAIN is stored

Figure 45: Train approaching station

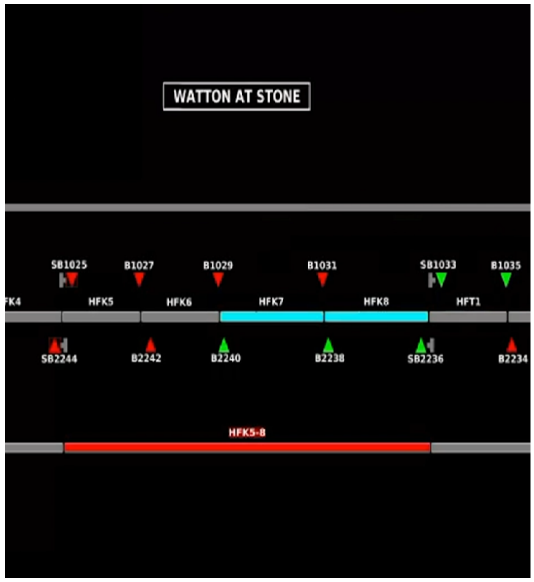

Figure 46: End of Mission

- SoM with the other cab:
  - The train does SoM and the L3 Trackside can establish the train location for the train.
  - When the Validated train Data are received as the train length matches the stored value in the L3 Trackside, is able to determine that is the same train
  - when the train reports with TI Confirmed the L3 Trackside changes the FVB with status Unknown to Occupied. No Unknown remains overlapped by the Occupied

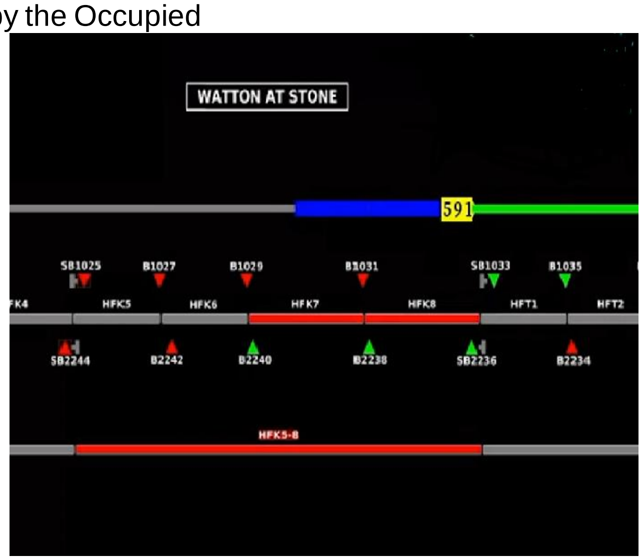

Figure 47: SoM in opposite direction

  - As the train moves off and the L3 Trackside establishes that the rear of the train has totally left a FVB, the FVB transits to clear.

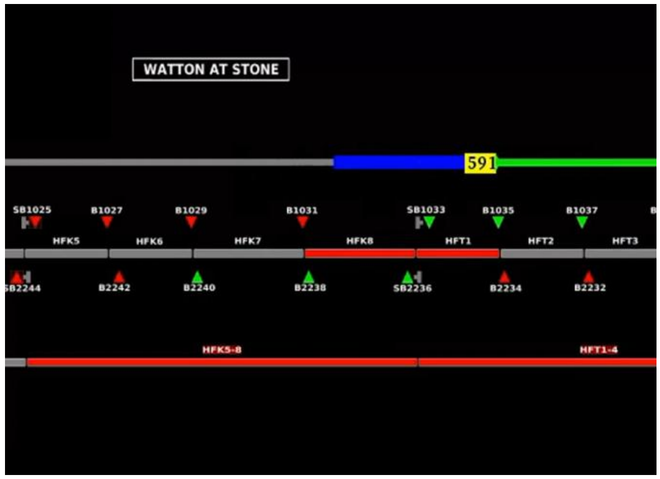

Figure 48: Train clear first FVB in rear of train

- When the train leaves completely the area where the train performed EoM, the track is clear.

15. **Loss of train integrity and recovery:**
    This scenario starts the same way as the normal train movement, but the forward train reports with Train integrity lost and the L3 Trackside prevents sending new MAs to the chasing train.

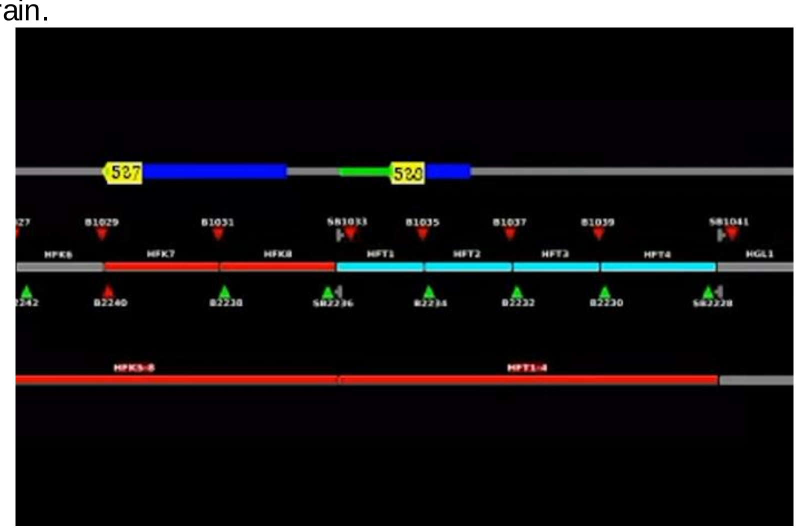

Figure 49: Train before Loss of Train Integrity

When the chased train reports Train Integrity lost, the FVB where the train is located become Unknown and no MAs are sent to the chasing train.

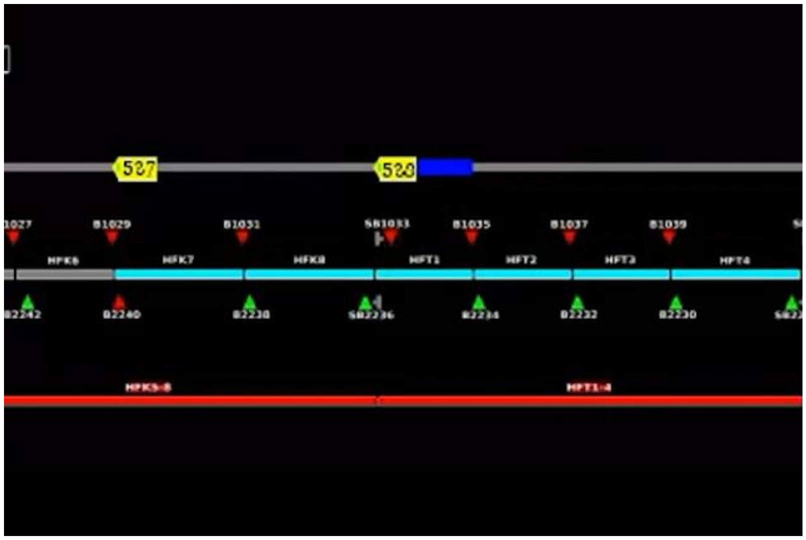

Figure 50: Train after Loss of Train Integrity

As the train moves forward and the front end of the train reaches a new FVB in the TTD, the train location is updated accordingly and the FVB becomes Unknown.

Figure 51: Train moves forward after Loss of Train Integrity

When the forward train leaves the TTD the FVB in that TTD become clear and the train can extend the MA for the chasing train.

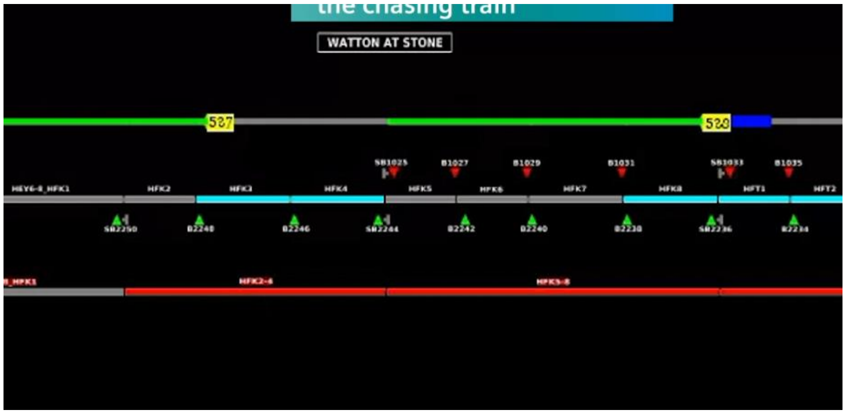

Figure 52: Rear of train clears TTD after Loss of Train Integrity

When the L3 Trackside receives a position report with Train Integrity Confirmed, the Unknown FVBs become Clear but the FVBs where the train is located which became Occupied. The MA for the chasing train is extended up to the border of the last Occupied FVB and both trains move off.

Figure 53: Train after reconfirming Train Integrity

16. **Loss of communications and recovery:**
    Two trains in normal movement and the forward train loses communications.

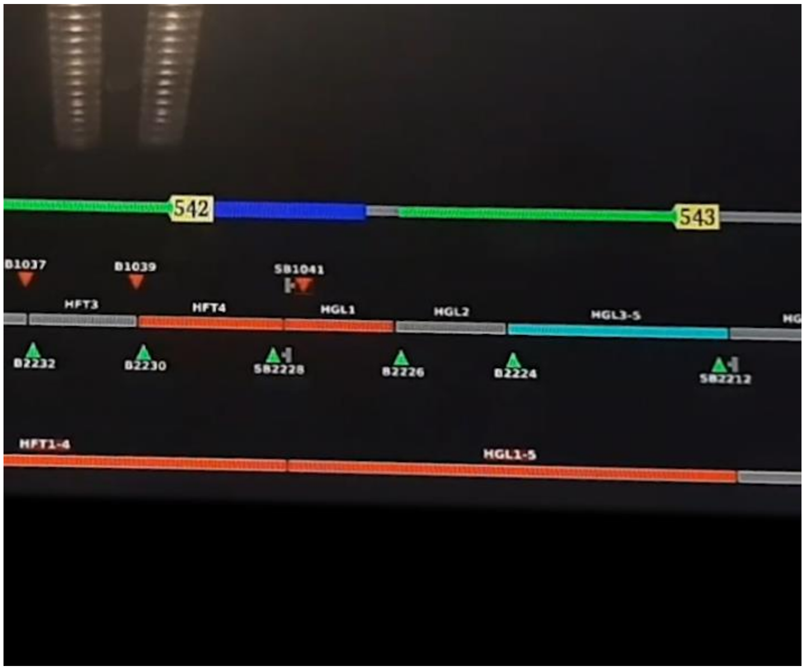

Figure 54: Train before Loss of Communications

The FVBs where this train is become Unknown to protect the train and extends the Unknown to the end of the TTD where the front of the train is, preventing the chasing train to get new MAs.

Figure 55: Train after Loss of Communications

The train enters the adjacent TTD and the Unknown Area is extended up to the end of the TTD section.

Figure 56: Train in Next TTD after Loss of Communications

When the L3 Trackside regains communications and receives train position reports with Train Integrity Confirmed by external device, updates the train location for that train, changes the Track Status FVB to occupied for the train location and longer MAs are sent to the chasing train.

Figure 57: Train after Regaining Communications

17. Sweeping: a train sweeps an Unknown area and recovers the track status.
Train on its approach to an Unknown Area to be swept

Figure 58: Train approaching an Unknown area

Figure 59: Train sweeping the Unknown area

TTDs: In all the above scenarios TTD status (received form the IXL) is considered by the L3 Trackside to determine the state of the FVBs of the line, together with the position information coming from the train via Position Report. In some scenarios the chasing train reports always TI lost so TTD are used to clear Unknown Track Status Areas.

All the figures in the document are snapshots from the video displayed to the WP members in Tres Cantos.

Conclusion:

The Technical Demonstrator was developed based on X2Rail-3 Requirements Specification, the aim was testing main line scenarios together with some SoM/EoM scenarios. As a proof of concept, the existing specification was proven valid for a FVB with TTD system.

During the development, and testing some issues were raised which feed the list of Open Points to solve the errors or missing gaps in X2Rail-3, for example the management of Reserved when a TTD becomes clear after loss of comms, or management of train location before the mute timer expiration.

5 Summary and Conclusions

Three separate realisations of the L3 Trackside system specified in X2Rail-3 D4.2 Moving Block Specification [X2R3D42] have been created for the three Moving Block Technical Demonstrators.

5.1 System Types

Table 2 below shows the different Moving Block System Types used in the three Moving Block Technical Demonstrators.

Task	Demonstrator	Supplier	System Type
Task 4.5	High Speed Line	Thales (TD)	Full Moving Block with TTD
Task 4.6	Low Traffic	Hitachi (STS)	Fixed Virtual Blocks with TTD
Task 4.7	Urban / Suburban	Siemens (SMO)	Fixed Virtual Blocks with TTD

Table 2: System Types for Moving Block Technical Demonstrators

All three of the Moving Block Technical Demonstrators are System Types with TTD. The System Types with TTDs are more complex than the System Types without TTDs, as it is necessary to include the algorithms for sensor fusion between the inputs from Train Position Reports (TPRs) and Trackside Train Detection (TTDs).

5.2 Scenarios Tested

Table 3 below shows the Normal Operation scenarios tested within the three Moving Block Technical Demonstrators.

Scenario	Task 4.5	Task 4.6	Task 4.7	Notes
Start of Mission	Yes	Yes	Yes	Includes SoM with changed direction
End of Mission	Yes	Yes	Yes	
Splitting	Yes			
Normal Train Movement	Yes	Yes	Yes	One train following another

Scenario	Task 4.5	Task 4.6	Task 4.7	Notes
Release of Points	Yes			
Level Transitions In and Out			Yes	

Table 3: Normal Operation Scenarios for Moving Block Technical Demonstrators

Table 4 below shows the Degraded Operation scenarios tested within the three Moving Block Technical Demonstrators.

Scenario	Task 4.5	Task 4.6	Task 4.7	Notes
Trackside Initialisation	Yes	Yes		Could be considered Normal Operation
Start of Mission Unknown Train Position		Yes		Interaction between TMS and L3 Trackside
Loss of Train Integrity	Yes	Yes	Yes	Also recovery
Loss of Communications	Yes	Yes	Yes	Also recovery
Sweeping	Yes	Yes	Yes	
SR Movement		Yes		

Table 4: Degraded Operation Scenarios for Moving Block Technical Demonstrators

5.3 Summary

The three Moving Block Technical Demonstrators have shown that it is possible to realise the L3 Trackside system specified in X2Rail-3 D4.2 Moving Block Specification [X2R3D42], albeit with some detailed issues to be resolved, as might be expected when a system is implemented based on such a specification.

In particular, the three Moving Block Technical Demonstrators have successfully implemented the Track Status concepts, including the sensor fusion between the inputs from Train Position Reports (TPRs) and Trackside Train Detection (TTDs).

There has been feedback from the Moving Block Technical Demonstrators into the work on X2Rail-5 D4.1 Moving Block Specification, which has allowed the issues revealed to be resolved in that updated specification.

6 References

The following references are used in this document:

[X2R3D42] X2Rail-3 deliverable:
D4.2 Moving Block Specifications
This is publicly available on the X2Rail-3 web site, under "Results and Publications"
https://projects.shift2rail.org/s2r_ip2_n.aspx?p=X2RAIL-3

7 Ownership of results

The following Table 5 lists the ownership of results for this deliverable.

Ownership of results			
Company	**Percentage**	**Short Description of share/ of delivered input**	**Concrete Result (where applicable)**
TD			
STS			
SMO			

Table 5: Ownership of results

This deliverable is jointly owned by the organisations listed above. The last three columns in the table are intentionally left empty.