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1 Executive Summary

This document contains the updates of the Stream2 Fail-Safe Train Position specification as part of the task 5.2.2 from X2RAIL-5:WP5. The objective of the document is to incorporate the new findings coming from standardisation activities on X2RAIL-5:WP5 as well as the results from X2RAIL5:WP7 demonstrators.

This document presents a major step towards the convergence possibilities of Stream2 and Stream1 with an updated architecture enabling the usage of reference locations based on a new functionality defined as Balise Telegram Reporter. The updated architecture is the convergence of large discussions and problem statements which combined with the results obtained in the demonstrators has concluded in an architecture that it is expected not to change completely the current legacy of ETCS but to allow the integration of enhanced positioning algorithms for the future.

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3 Abbreviations and acronyms

Abbreviation / Acronyms	Description
ATO	Automatic Train Operation
C.I.	Confidence Interval
CMD	Cold Movement Detection
DFMC	Dual Frequency Multi Constellation
EGNOS	European Geostationary Navigation Overlay Service
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
ETCS-OB	ETCS On-Board
E_ODO_TS	Enhanced odometry Track Side.
E_ODO_OB	Enhanced ODOmetry On-board.
GNSS	Global Navigation Satellite System
LRBG	Last Relevat Balise Group
SIL	Safety Integrity Level
SFA	Safe Fusion Algorithm
SNCF	Societe Nationale des Chemins de Fer
STM	Specific Transmission Module
TD	Thales Deutschland
WP	Work Package

4 Background

The present document constitutes WP5's Deliverable D5.2 "Stand Alone Fail-Safe Train Positioning Specification". The Deliverable is part of the framework of the Project titled "Completion of activities for Adaptable Communication, Moving Block, Fail safe Train Localisation (including satellite), Zero on site Testing, Formal Methods and Cyber Security" (Project Acronym: X2Rail-5; Grant Agreement No 101014520).

5 Objective / Aim

The aim of this document is to present an updated version of the architecture and specification defined in X2RAIL-2:WP3 for the Fail-Safe Train Position-stream2 definition. The update is based on the work carried out in the context of X2RAIL5-WP5 standardisation activities as well as in the results obtained from X2RAIL5-WP7 demonstrators.

6 Introduction

In the context of X2Rail2 it was defined a system requirement specification [1] and a reference architecture [2] for Fail-Safe Train positioning as understood by Stream2. In X2Rail5 there have been defined two main tasks related to these inputs. On one hand WP7 is responsible for developing a demonstrator based on these specifications where the goal is to perform a feasibility study on the algorithms respecting the architecture specification and feeding back the results to WP5. On the other hand, a standardisation activity planned within the context of WP5, namely “Task 5.3 Gap Analysis, roadmap and migration strategy”, has the goal to close the gaps between the current specification and its integration on existing ETCS legacy. Furthermore, this task has also the goal to close the divergence between the two streams and to find a way of convergence for a unique standard solution. The result from all these activities has led to a new architecture with new functionalities that are presented here. It is expected that WP5 will embrace these results as part of the Task 5.3.2 Roadmap and Migration Strategy.

In section 7 an overview of the inputs presented in [1] and [2] is carried out. In section 8, an updated architecture is proposed, in section 9 an updated interfaces for the updated architecture is described and in section 10 an updated system requirement specification is described. Finally, the document is closed in section 11.

7 Heritage Specification

7.1 System Requirement Specification

In the context of X2rail-2, WP3 defined a system requirement specification for the Stand Alone Fail-Safe Train positioning – Stream 2 development [1]. In this specification there are three cornerstones highlighted here after: requirements for position along the track, requirements for speed and environmental requirements. For further details the reader is invited to read [1].

In terms of position requirements along the track, it is defined a requirement similar to current ETCS subset 41 legacy, where the expected performance of the confidence interval is "Fail-safe train positioning shall calculate train's front position with a maximum confidence interval of +/-10 meters within speed intervals from zero to 40km/h, 40km/h included. For speeds greater than 40km/h and lower or equal to 500 km/h the confidence interval shall be equivalent to a distance run in one second", taken from [1]. The major difference to the current legacy is that it defines a minimum error of 10m, which in Subset 41 is defined as 5m. In the following Figure 7-1 it is illustrated the shape of the requirements in a graphical mode.

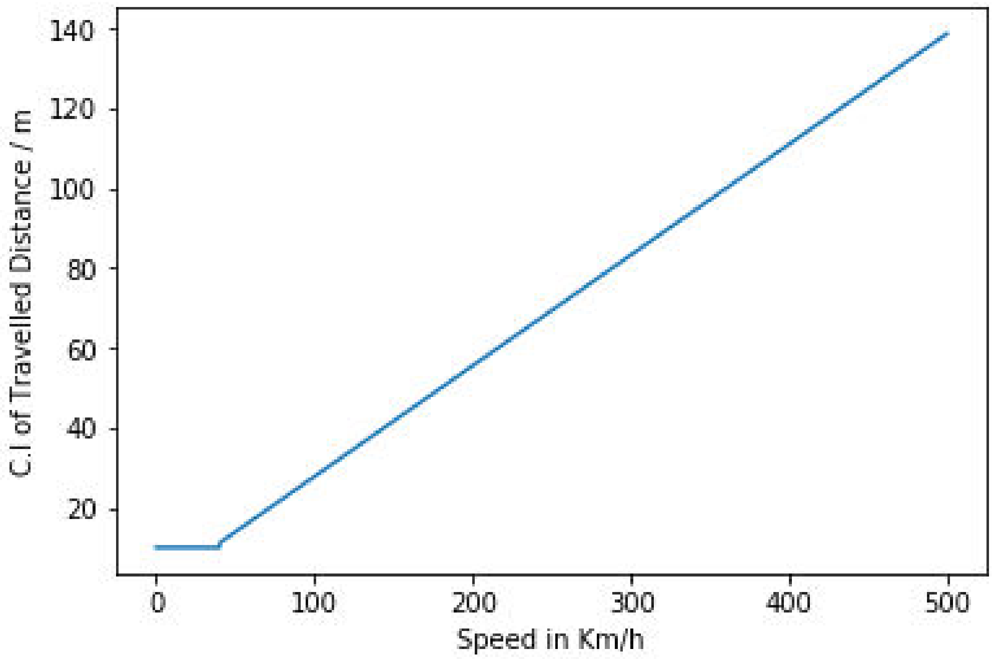


Figure 7-1 Position Maximum confidence interval representation as defined in X2RAIL-2 [1]

Similar to position requirements, speed requirements are defined as "Fail safe train positioning shall calculate train's speed with a maximum confidence interval of +/-2km/h for speed lower than 30km/h, and then increasing linearly up to 12km/h at 500km/h", taken from [1]. In the following

Figure 7-2, it is illustrated the shape of the requirements in a graphical mode. In this case there is no change with respect to the current ETCS legacy.

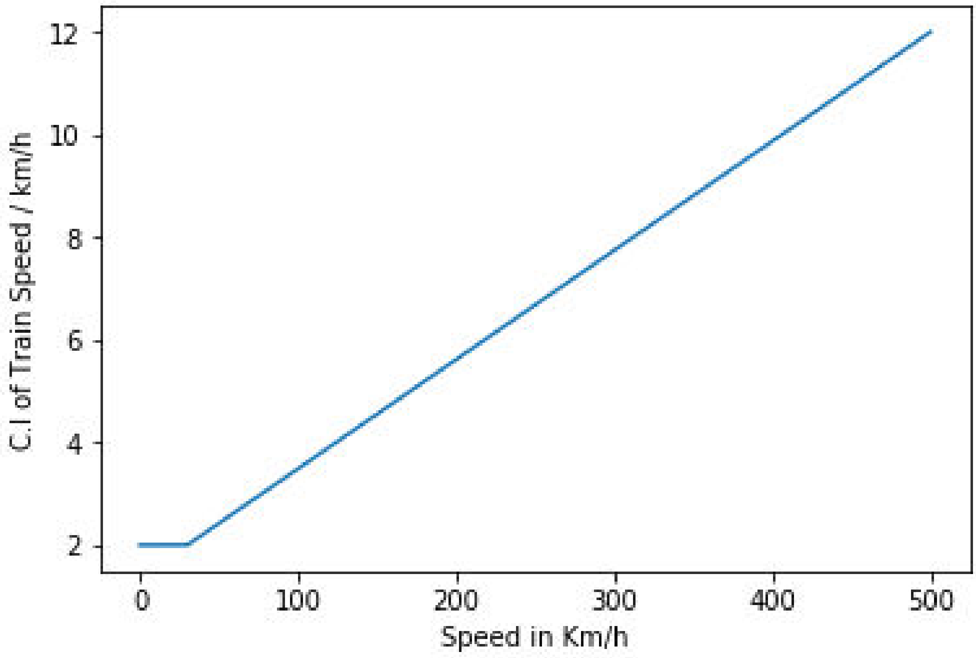


Figure 7-2 Speed Maximum confidence interval representation as defined in X2RAIL-2 [1]

Finally, the section 7.3 in [1], also specifies that the previous two functionalities shall work under all environmental conditions, such as tunnels, bridges etc, and under any meteorological conditions, such as rainy, sunny, snowy etc.

7.2 Architecture

In the context of X2rail-2, WP3 defined an architecture for the Stand Alone Fail-Safe Train Positioning – Stream 2 development [2]. The specification first looked at the hight level architecture considering both trackside and on-board side. In Figure 7-3 it can be seen two main entities, E_ODO-TS and E_ODO-OB. E_ODO-TS refers to the “Enhanced Odometry from Track Side” and E_ODO-OB refers to “Enhanced Odometry from On-Board”. E_ODO-TS is responsible to provide any additional data that E_ODO-OB may require to performs its tasks. E_ODO-OB is responsible to estimate speed, position of the front of the train to any other subsystem on the train, for instance the ETCS-OB.

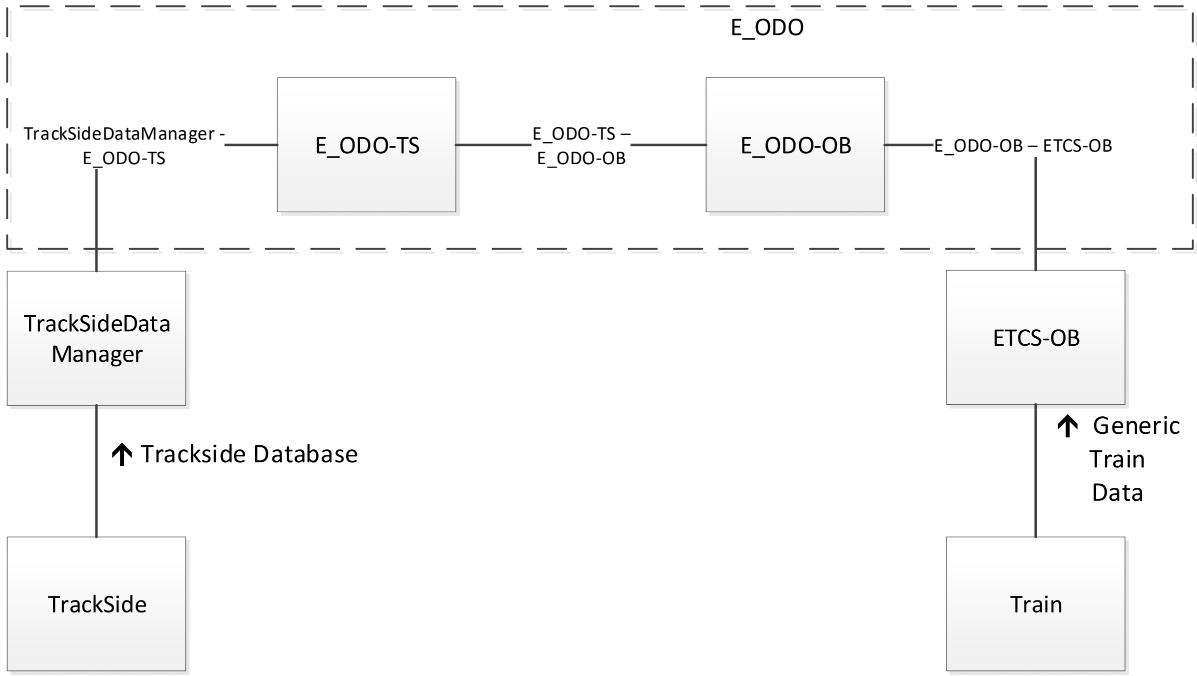


Figure 7-3 High level Architecture definition from X2RAIL-2 [2].

In Figure 7-4 it is shown the insight architecture specification of the E_ODO-OB. In this illustration the system defines interfaces to sensors, such as GNSS sensor, Accelerometers, Gyroscopes and Wheel Angular Speed sensors. In addition, it also allows to receive information from trackside such as a digital map or augmentation information for GNSS as well as some practical information from ETCS-OB such as active cab (depicted as Train Dynamic Data) , Cold Movement Detection (CMD) or Balise identifiers. All these inputs lead to the Safe Fusion Algorithm (SFA) that is responsible to estimate a safe front train position and speed. The output of this functional block then feeds into other subsystems in the train such as the ETCS-OB and it could also be sent to E_ODO-TS. In order to retrieve the information from track side a “Data Client Manager” functional block is defined as a gateway to E_ODO-TS. Finally, a “Position Reporting Manager” is responsible to send back to E_ODO-TS the positioning information so that it can be used by trackside.

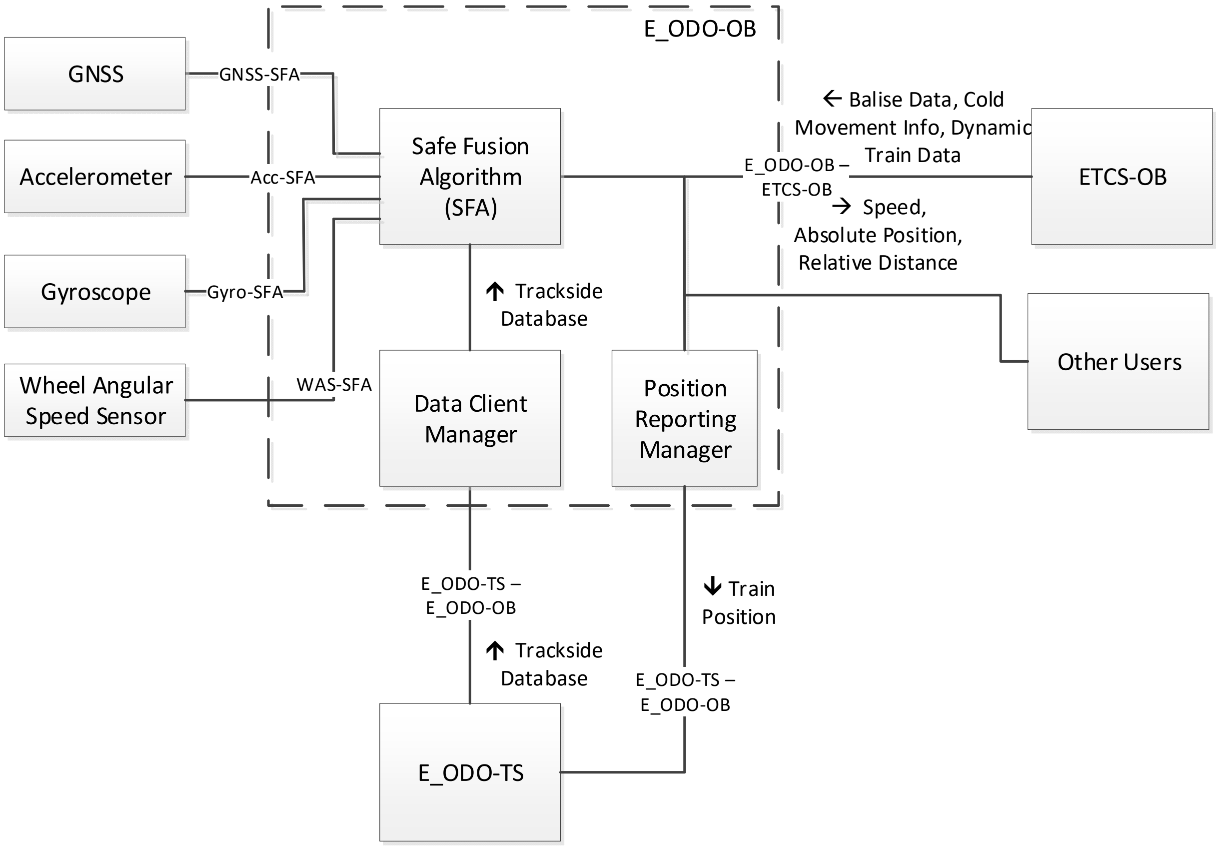


Figure 7-4 Architecture definition for on-board side from X2RAIL-2 [2].

8 Architecture update

8.1 Gap identification and Scope for the updated Architecture

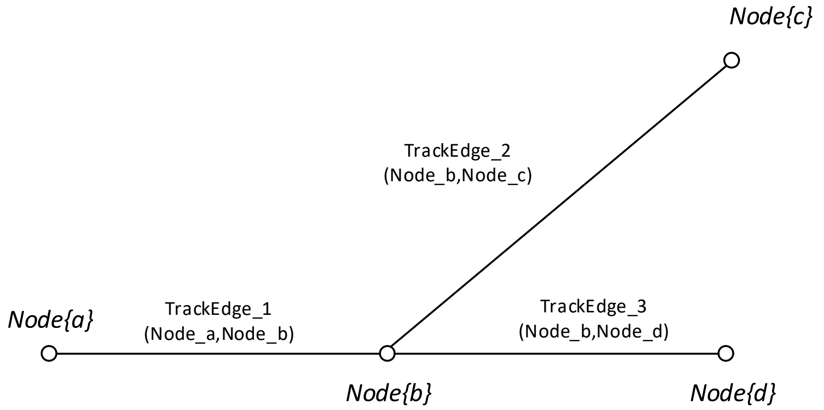
The architecture proposal in [2] is a generic solution for a positioning system that does not explicitly address its integration with current existing ETCS/ERTMS system. Furthermore, current ETCS/ERTMS system solves the problem of positioning with Balises, which means that the entire system is defined around the travelled distance to the Last Relevat Balise Group (LRBG). At this stage there are two options, either a completely new paradigm is defined for ETCS/ERTMS to integrate a continuous absolute positioning system or the positioning system finds its way to provide a smoother integration on ETCS without changing as much the current concept. In the context of X2Rail-5 the proposal is to try to find an integration of the positioning system into ETCS/ERTMS respecting the bases of today implementation.

The scope of the new proposal is targeting the integration of the positioning system into ETCS leaving aside any other use case such ATO, train integrity any other that may require positioning information. This means that the output functions that estimate heading, roll or pitch angles of the active cab are not part of the E_ODO-OB output, although this information may be used internally by the positioning algorithms. In addition, it is agreed that the E_ODO-OB shall calculate the position of the vehicle body at a fix point and it does NOT attempt to calculate the active cab's safe front end. It is assumed that the deduction of the active cab is part of the ETCS functionality and does not belong to E_ODO-OB. This also simplifies the functionalities to be carried out by E_ODO-OB and removes the dependencies on knowing which cab is active, train length and train integrity information too. Finally, the E_ODO-OB integration into ETCS is already considered complex problem to solve, consequently the E_ODO-TS is not really targeted in this proposal.

8.2 Definitions

In the context of X2RAIL-5 it has been identified a lack of definitions or mis-conception that needed to be clarified. In this context

Concept	Definition
Digital Map	A digital map is based on a topological model of track edges and track nodes. Track Nodes are defined as a position on a topological model of the beginning and end of a track edge [5]. Track Edges represent one physical track that connects a start node with an end node. Each track edge has a fixed nominal direction and a reverse direction, sometimes also named as up/down directions.

	 **Figure 5 Topological representation of the digital map.** For each position on the track edge multiple information can be added to the digital map. For instance, curvature profile, gradient profile or GNSS data, a list of sequenced latitude and longitude pair of information, can be used to enrich the information of the digital map. In turn, this information could be used by the fusion algorithm to estimate a position. Furthermore, the digital map can also store additional data such as reference locations which, along with some balise telegram information, could become useful data to report crossed geolocations to the ETCS-OB.
Reference Location Definition	Subset 023 [4] already defines Odometry reference location as "The reference location to which refers the train-based odometer distance reading". In this paper, "reference location" is referred to a common geographical point along the track, on centre line and with orientation. A reference location can either represent a physical balise, defined by its physical location and orientation, or a defined location along the track combined with the orientation of the underline track edge. The start or the end of a track edge can also be defined as a reference location; however, it is expected that the digital map may integrate dedicated reference locations to report positioning information to the ETCS
Confidence Interval	Confidence Interval is a boundary defined as the Under/Over reading amount of a measured or estimated value, for instance for speed, within which the true value lies with a certain probability
Speed Intervals	Two type of speed intervals are defined:

<table>
<tr><td></td><td>- Constant Speed: For the following subsections, “Constant Speed” is considered whenever the averaged true acceleration for 5 seconds does not exceed +/- 0.2 m/s2.
- Transition Speed: For the following subsections, “Transition Speed”, that is acceleration/deceleration speed, is considered whenever the train is not in “Constant Speed”.</td></tr>
<tr><td>Sensor Failure</td><td>A sensor failure is considered any time a hardware failure or communication error occurs between the sensor hardware and functional reader. The lack of information or misleading information due to environmental conditions are not considered sensor failure. For instance, slip and slide from a tachometer is not a sensor failure, but the detection of a wire cut on a tachometer is considered a sensor failure. Similarly, a GNSS outage is not considered a sensor failure; however, an error in communication channel for raw data is considered a failure</td></tr>
<tr><td>Reference Location System</td><td>The reference coordinate system E_ODO-OB is using is defined as a fixed point in the vehicle-body. An example of this reference system is illustrated in Figure 6 where the active cab A of the train consist is depicted as blue triangle of the active train unit and the non-leading train unit’s cab B is depicted with green stripes. With this set up, if the train is moving from the active train unit’s in the direction of Cab B to Cab A then the speed value estimated by this coordinate system is negative. Notice that ETCS will require to know in advance as part of its configuration parameters the position and orientation of this reference system before it can use it, as it is the case for instance for tachometer mounting direction parameter now a days.

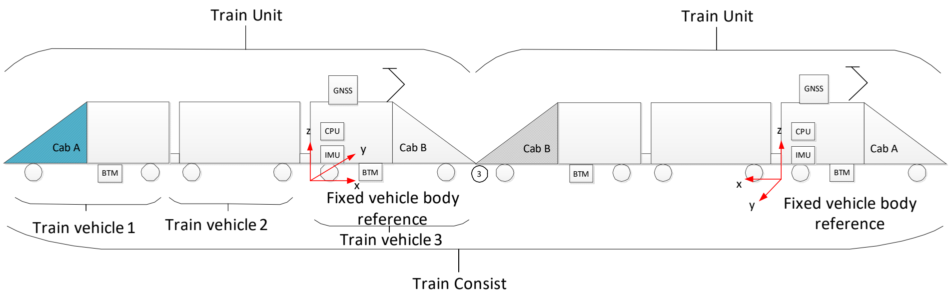


Figure 6 Coordinate reference system for E_ODO-OB with example localisation sensors.</td></tr>
<tr><td>Accumulative Travelled Distance</td><td>This value refers to the travelled distance since switch on regardless of the direction of the travelled value, that is summing up absolute value of the travelled distance since switch on</td></tr>
</table>

Accumulative Travelled Distance Reliability	The “Accumulative Travelled Distance Reliability” is defined as the mean time between two events that exceed a defined error limit whenever no failure is encountered on sensors and excluding maintenance errors. Notice that Maintenance error is considered any error occurred introduced by human action in the maintenance process of the localisation unit. For instance, whenever a new wheel diameter needs to be updated on the ETCS configuration and the introduced value is not aligned with the wheel diameter installed.

Table 1 Table definition for stream2

8.3 Updated Architecture Proposal

In the following Figure 7, it is illustrated an updated architecture with two principal blocks identified in blue. On the left side E_ODO-OB is the main function to estimate position, speed and to report balise telegrams to ETCS-OB whereas on the right side the E_ODO-OB integrator is an additional functional block required on the ETCS side to integrate received data into its existing functionalities.

Within the responsibility of the E_ODO-OB there are four main functional blocks:

- *Safe Fusion Algorithm* (SFA) functional block
- *Balise Telegram Reporter* functional block
- *Localisation Sensors* functional block
- *Data Client Manager* functional block

Notice that all internal interfaces within the E_ODO-OB are not expected to be standardised interfaces whereas the interfaces between E_ODO-OB subsystem and ETCS-OB and the interface between E_ODO-OB subsystem and E_ODO-TS shall be standardised.

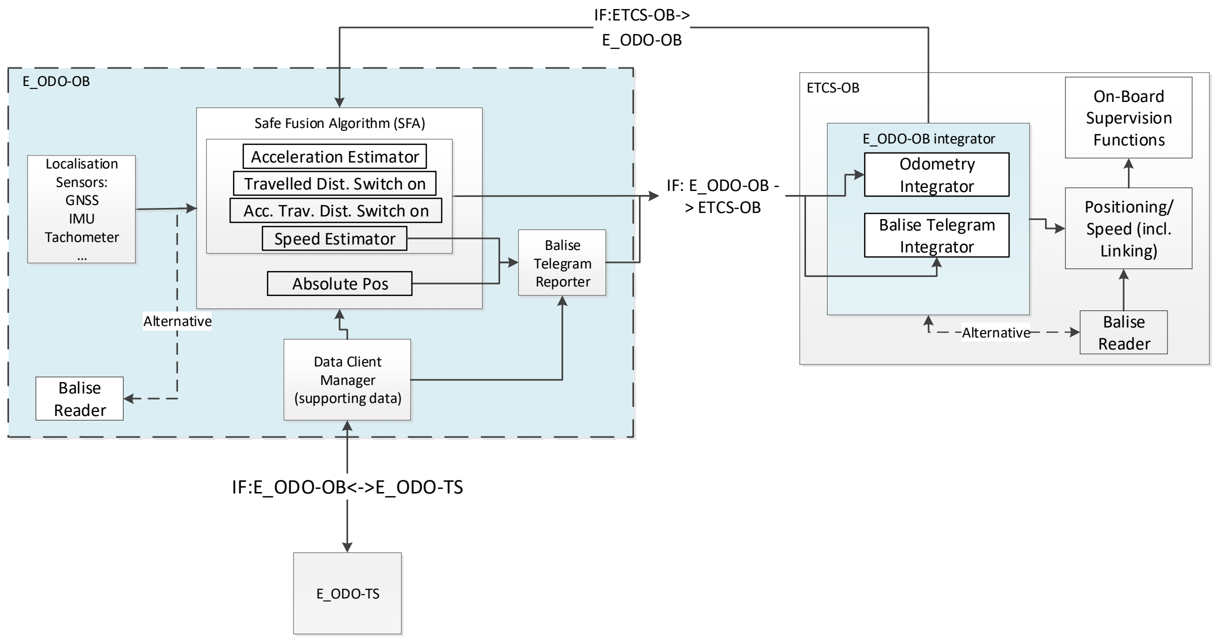


Figure 7: Architecture definition for Stream2 (upgrade in blue with respect to X2R2 defined architecture)

The *Safe Fusion Algorithm* (SFA) is the functional block that interfaces with the ETCS-OB. This functional block is divided into four main functions:

- Absolute Position Information Estimator
- Speed Estimator
- Travelled Distance since Switch On Estimator
- Accumulative Travelled Distance since Switch on Estimator
- Acceleration Estimator

The *absolute position information* from SFA is understood as the position that can be represented by a single-track edge and a distance from the start of that track edge (see definitions on Table 1).

For that purpose, the SFA uses data from *Sensors* functional block, *Data Client Manager* (for digital maps and augmentation information, if any) and E_ODO-OB inputs.

Since current state of the art on GNSS does not guarantee track discrimination with a SIL4 requirement, it is assumed that the read physical balise data is included as part of the input to the SFA. For this information there are two alternatives not decided at the stage of this proposal:

- On one hand, the physical balises read from ETCS are sent to the E_ODO-OB through the *IF: ETCS-OB->E_ODO-OB* interface.
- On the other hand, Balise reader itself is part of the E_ODO-OB sensor and thus every physically read balises shall be reported to ETCS-OB.

Notice that the described absolute position makes a reference to a fix point at the train vehicle in which the main sensors are installed. In other words, SFA is NOT responsible to calculate active cab's position, as this remains an ETCS-OB responsibility. However, the consumer of E_ODO-OB may require knowing this fixed point at the vehicle, which is considered a configuration information similar to the case of a tachometer sign known by ETCS-OB.

In addition, the absolute position information shall also be provided with a confidence interval which is based on the best effort of the algorithm. In other words, the CI provided by this information can shrink and grow without any restrictions.

The *speed estimator* function is responsible to estimate E_ODO-OB speed value and its confidence interval. It is expected that the estimation is used by the Balise Telegram Reporter function and by the ETCS-OB system as pure odometry information.

The *travelled distance since switch* on function is responsible to estimate travelled distance and its confidence interval since switch on. The confidence interval related to this function is a never shrinking confidence interval as it is for today's ETCS-OB odometry system. This is necessary to allow a seamless integration of this information within ETCS-OB. Notice that information is expected to be used by ETCS-OB to recalculate its confidence interval and to comply with STM requirements, see SUBSET-035 §8.3 [6].

The *accumulative travelled distance since switch on* function is the travelled distance since switch on regardless of the direction of the travelled value, that is summing up absolute value of the travelled distance since switch on. The main purpose of this information is to facilitate the performance of the overall algorithms of E_ODO-OB.

The acceleration estimation function is responsible to estimate acceleration value. This information is necessary for ETCS-OB to comply with the T_traction value for the braking curves, SUBSET-026-3 §3.13.2.2.2 [7].

The Balise Telegram Reporter functional block is responsible to possibly report a balise telegram whenever the E_ODO-OB crosses a reference location defined in the digital map. Recall that reference locations as per definition can be a common geographical point along the track, on centre line and with orientation, so it can either be a physical balise, a virtual balise or any other meaningful geographical point. The functional block uses the absolute position and speed information from SFA to decide whether E_ODO-OB shall trigger a balise telegram report or not. This balise telegram report includes balise telegram bits stored in the digital map, the dynamic confidence interval calculated at the time the balise telegram is crossed and the corresponding time and odometer stamp information (see [8] §4.2.4.2). Notice that the confidence interval provided by this function shall bound the position error of E_ODO-OB and the error defined in the digital map for theoretical localisation of balise telegram in the digital map.

With regards to *Data Client Manager* functional block, it is responsible to retrieve from track side all required supporting data. This includes managing safe communication channel with track side and to retrieve an updated digital map and augmentation information if any.

Finally, *Sensors* functional block refers to all required sensors by the SFA to estimate all defined functions previously in this section.

On ETCS-OB side, the *E_ODO-OB Integrator* has two-fold functionality. On one hand to integrate read balise telegrams from E_ODO-OB as inputs to the current positioning functionality on ETCS as if they were physical balises. On the other hand, the odometry functionality, typically carried out by ETCS-OB, is now received by E_ODO-OB and this information must be integrated into the positioning and speed functions of the ETCS-OB. Similarly, to what is described in E_ODO-OB, the balise reader can either be located at the E_ODO-OB side or ETCS-OB side so far. For this reason, if the balise reader is to stay at the ETCS-OB, then the balise reader requires odometry speed value and in turn it returns read balise telegrams to the E_ODO-OB (see bidirectional arrow from balise reader to *E_ODO-OB Integrator*). On the contrary, if the balise reader is moved to the E_ODO-OB all these functionalities could be removed from ETCS-OB.

The *odometry integrator function* is responsible to manage the travelled distance since switch on and its confidence interval, speed estimator and its confidence interval and acceleration values. These values shall be received by the ETCS-OB timestamped and cyclically.

Notice that the odometry integrator function receives information referred to a fixed position with a fixed orientation at the vehicle body frame. As such, travelled distance since switch on is expected to increment whenever the train moves in a fixed direction and decrease whenever it goes in the opposite direction. However, for the confidence interval related to the travelled distance, the value shall be always a non-shrinkable value. For the speed value the sign is also fixed to the vehicle body frame, and it is the responsibility of ETCS-OB to translate that to the appropriate sign based on active cab and train running direction. Recall that this fixed body frame translation is already a task performed by current ETCS-OB for tachometers where the sign value of the tachometer is typically a configuration parameter for ETCS-OB.

8.4 Summary of the changes from previous architecture

In the following list, it is summarised the main changes that apply for each function block with respect to its original description defined in [2]:

- The Safe Fusion Algorithm (SFA) block:
    - In the new architecture SFA is still responsible to estimate the absolute position, speed, travel distance and acceleration. However, it is now referred to the fix body frame instead of the front of the train.
    - CMD is currently out of the scope of this functional block.
- Balise Telegram Reporter:
    - There is a new function named Balise Telegram Reporter which is responsible to detect reference locations within the digital map and report them as balise telegram bits to the ETCS-OB
- Data Client Manager:

    - In the current version the arrow to track side is bidirectional. This is understood as an interface that will require some interaction with track side to retrieve supporting data. So far supporting data can either be digital map and/or augmentation information.
- ETCS-OB:
    - ETCS-OB does not need to provide the active cab nor train length to the E_ODO-OB anymore.
    - CMD is by now out of the scope of this analysis.
    - New functional block named as E_ODO-OB Integrator assumes that ETCS-OB provides time synchronisation data to E_ODO-OB so that the received input from E_ODO-OB is timestamp-ed with ETCS time value.
    - ETCS-OB still needs to send read physical balise information to E_ODO-OB if the alternative to integrate balise reader on E_ODO-OB is not carried out.
    - ETCS-OB receives balise telegrams from E_ODO-OB which are based on E_ODO-OB positioning and digital map data.
    - ETCS-OB still retains the responsibility of calculating the LRBG and DLRBG.
    - ETCS-OB still retains the responsibility of calculating the safe front and rear end of the train.
    - ETCS-OB is expected to have an E-ODO-OB Integrator function to adapt received information to existing ETCS-OB architecture.
- Sensor:
    - Sensors are not treated individually with its own interface but rather as internal inputs to the SFA.
    - The balise reader is now an open point. This sensor could either be integrated as part of the sensor block or it could stay as the current legacy on ETCS side but then physical balises need to be reported from ETCS-OB to E_ODO-OB.

9 Interface Specification Update

The architecture update presented in section 8 proposes interface changes with respect to the previous architecture. In the following subsections these interfaces are described. Notice that these are the interfaces subject to be standardised.

9.1 Inputs to E_ODO-OB

"*IF:ETCS-OB->E_ODO-OB*" defines the input information received from ETCS-OB by the E_ODO-OB to perform its functions. The following list of inputs are expected:

- Timestamp: Current time of the ETCS-OB so that any information sent from E_ODO-OB to ETCS-OB can be correctly timestamped.
- Balise Telegram Information: It refers to NID_C, NID_BG and N_PIG values from a balise telegram as defined in SUBSET-026-8 §8.4.2. [7]and the Q_LOCACC of the received balise, see SUBSET-026-7 §7.5.1 [7].
    - Notice that this information is subject to the alternative presented in the architecture and may not be necessary if the Balise reader is part of the E_ODO-OB.

"*IF:E_ODO-TS->E_ODO-OB*" defines the input information received from E_ODO-TS by the E_ODO-OB to perform its functions. The following list of inputs are expected:

- Digital Map: The digital map shall contain all required information to allow E_ODO-OB position the system and report a balise telegram to ETCS-OB whenever a reference location is crossed.
- Augmentation information: if required by the SFA it is possible to obtain GNSS augmentation information to provide integrity and accuracy to the GNSS signal received by GNSS sensors. In the case the augmentation is needed the work carried out in [9] should be considered as a reference.

9.2 Outputs from E_ODO-OB

"*IF: E_ODO-OB->ETCS-OB*" defines the output information sent from E_ODO-OB to ETCS-OB. The following list of outputs are expected:

- Balise Telegram Reported information (bits as defined in the digital map plus confidence interval) whenever necessary
- Speed and its confidence interval with respect to the fixed body frame on the train periodically.
- Travelled distance and its confidence interval since switch on periodically.
- Accumulated Travelled distance since switch on periodically.
- Acceleration value at the fixed body frame on the train periodically.

"*IF: E_ODO-OB->E_ODO-TS*" defines the output information sent from E_ODO-OB to E_ODO-TS. In this interface two main information is expected. The first one related to establish a safe communication from on board unit to track side. The second one is the exchange of message that may be required to retrieve both the appropriate update of the digital map and/or augmentation information for sensors.

10 System Requirement Specification Update

In the context of X2Rail-5 there have been two main sources of information to update the system requirement specification defined in [1]. On one hand, it is the work carried out as part of standardisation activities which has led to a new architecture specification defined in section 8. On the other hand, the demonstrators developed in X2Rail5-WP7 are based on the functional block named as SFA defined in the original architecture presented in [2]. Since the updated architecture and the current proposed architecture are not the same the results from X2Rail5-WP7 cannot be directly used into a new specification. Nevertheless, the feedback from WP7 is still valid as their target has been the localisation algorithm performance feasibility study and not the architecture itself.

The results from WP7 are summarised in [3], where three different demonstrators with different dissemination levels have shown the feasibility of GNSS based algorithms for safe positioning. CAF solution has a real-time demonstrator with an algorithm that could lead to a positioning system of around 20 meters fixed error. SNCF has shown a positioning algorithm with an emulator of EGNOS DFMC with errors values below 3 meters on post processing mode with a favourable GNSS environment. TD has shown a real-time implementation as part of the dual architecture solution where larger errors compared to SNCF solution have encountered. In this case it has been demonstrated that the GNSS environment for TD is worst that the one shown by SNCF results. All three demonstrators have been performed in different tracks with different trains at different environmental conditions.

Due to the large difference in result from the three demonstrators as well as the impossibility to compare them directly, it is not possible to conclude that the 10 meters error defined in section 7.1 could/should be changed to either 20 meters or 3 meters. In other words, the specification defined in [1] remains valid in terms of SFA performance values for position and speed accuracy.

11 Conclusions

This report describes an updated architecture proposal where both E_ODO-OB and ETCS-OB are expected to include new functionalities. E_ODO-OB shall now integrate a new functionality for Balise Telegram Reporting whereas the ETCS-OB needs to define a functional block to integrate this new reference from the Balise Telegram Reporting in its current legacy. This updated proposal enables to find strong commonalities between stream 2 and stream 1 developments as defined in X2RAIL2:WP3 which could potentially now find a convergence point within task 5.3.2. Recall that task 5.3.2 has the mandate to define the roadmap and migration strategy and consequently, finding strong synergies within this work should provide good hints to the next steps. In addition, the demonstrators shown in WP7, which have been mainly targeted to positioning algorithms, have shown that proposed performance values in [1] are not far apart to what has been seen in real-time scenarios.

In the near future it is advisable to integrate the updated architecture proposal and to perform an analysis on the commonalities with Stream1, to find a unique solution for the Fail-Safe Train Position specification.

12 References

[1] X2R2 D3.8 Stand Alone System Requirements Specification for Fail-Safe Train Positioning V 06

[2] X2R2 D3.9 System Architecture Specification and System Functional Hazard Analysis for Stand Alone Fail-Safe Train Positioning V 05

[3] X2RAIL-5-T7_5-D-CAF-015-03 Stand Alone Fail-Safe Train Positioning Demonstrators: Prototypes, Developments, Analysis and Test Report

[4] ERA * UNISIG * EEIG ERTMS USERS GROUP, Subset 023 - Glossary of Terms and Abbreviations, version 3.3.0

[5] CLUG – WP3 - D3.1.2.5_DigitalMap_v2.6_CO_final.pdf

[6] ERA * UNISIG * EEIG ERTMS USERS GROUP, Subset 035 – Specific Transmission Module (FFFIS). version 3.1.0

[7] ERTMS/ETCS System Requirements Specification Subset-026 issue 3.6.0

[8] ERTMS/ETCS FFFIS for Eurobalise Subset-036 issue 3.1.0

[9] System Requirement Specification EUG Solution for Enhanced Onboard Localisation Change Request (CR1368) – GNSS Augmentation for ERTMS/ETCS 20E085 issue, 31/05/2022