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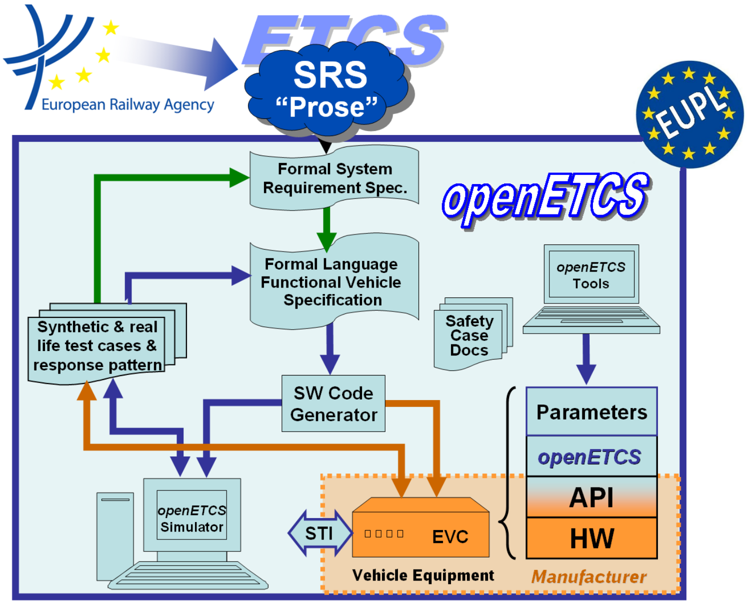
Work-Package 3: “Modeling”

# openETCS System Architecture and Design Specification

**Third iteration: Scope of openETCS ITEA2 Functions**

Baseliyos Jacob, Bernd Hekele, Peyman Farhangi, Stefan Karg, Uwe Steinke, Christian Stahl, David Mentré, David Mentre, Jos Holtzer, Jan Welvaarts, Vincent Nuhaan and Jacob Gärtner

November 2014

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## Document approbation

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Architecture and Functional Specification

Prepared for openETCS@ITEA2 Project

**Abstract:** This document gives an introduction to the architecture of openETCS. The functional scope is tailored to cover the functionality required for the openETCS demonstration as a target of the ITEA2 project: the Utrecht Amsterdam use-case. It has to be read as an add-on to the models in SysML, Scade and to additional reading referenced from the document.

# Modification History

| Version | Section | Modification / Description | Author |
|---|---|---|---|
| 0.1 | Document | Initial document providing the structure | Baseliyos Jacob |
| 0.2 | Document | Workshop Results included and some pretty-printing | Bernd Hekele |

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# Figures and Tables

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# 1 Introduction

## 1.1 Motivation

The openETCS work package 3 (WP3) aims to provide – amongst others - the software architecture for the openETCS kernel in order to eventually build the software itself. WP3 partner has put great effort in the openETCS software design, thus far without making definite choices on the software architecture itself respective of functional breakdown and data structures of the openETCS kernel. Since the project planning foresees in the production of a reference software to be used as a demonstrator by June 2014, it is of paramount importance that a design freeze of the openETCS kernel architecture be finalized shortly but no later than November 2014.

In compliance with the agreements made during the last WP 3 meeting at the 10.09.2014 in Brussels, DB has taken the initiative to design the aforesaid architecture including of functional breakdown and data structures in order to safeguard a timely delivery of these products. Furthermore, DB has ensured that these developments are focused on including end user requirements so as to develop a design in conformity with the needs and requirements of the operators. Specialists of DB and NS have cooperated together with other partners in WP3 to produce this document.

As referred to above, the architecture description has to be finalized in the month of November 2014. This version of the document is a draft version, demonstrating the general directions and philosophy of the architectural design, the functional breakdown of the software and the data structures. The design is focused on maximum efficiency in order to maximize on RAMS performance of the end product.

**This document, named second iteration, is a draft document and will be developed until a complete architecture.**

Since this is a work in progress, any remarks referring to the improvement of the document, including reporting errors, are more than welcome. Any additional work done thus far on the subject by other WP3 partners will be incorporated in this document as long as it is aligned with and consistent or complementary to the fundamental viewpoints advocated in this document after a review in respect to the openETCS process. At the same time, any contributions to the integration of which will demand discussion or changes of the fundamentals as proposed in this document, will be discarded with . Only in this way the ITEA2 project is able to meet its objectives as mentioned above. There will be two workshops in which there is due time and opportunities to fine-tune this document and its contents. Any comments will be addressed there.

It is urgent to definitely finalize the architecture on a short notice and therefore this document will rather prescribe than describe the openETCS architecture, functional decomposition of the system and the data structures within the limits as stated above. The document is divided in two parts, i.e.:

• A description of the general architecture of the openETCS OnBoard Kernel (software) including data structures prepared by NS. . . .
• A description of the functional decomposition of the openETCS OBU (software) in alignment with the general architecture prepared by DB. . . ..

Furthermore, this document describes the preconditions on which said descriptions are based on, the status and planning of upcoming activities and the main objectives of DB and NS as the End User. Wherever necessary, reference will be made to documents that underline the agreements that have been made during the openETCS architecture design process and the activities and meetings of WP3.

## 1.2 Objectives

The prime objective of WP3 is to produce a rapid prototype for the openETCS reference system that can function as a demonstrator in collaboration with WP 4 and WP 5 for the openETCS approach and will be used as such in the final phase of the project. That phase is the first half of 2015. This objective is defined as . . .

**High level Objectives of this work:**
«any further general statements on the ITEA2 objectives, like. . . »
• Work on a model bases approach and process for effective collaborative work within an international ETCS developer team as stated above, the project needs a definite architecture design by the end of 2014. This document targets:
• Defining the general design and conditions of the openETCS architecture, functional breakdown and data structures;
• Providing the guidelines for discussion during the workshops that are planned in October and November 2014 that will result in the final and decisive version of this document;
• Being the 'platform' for finalization i.e. whatever be the products or results of the workshops shall be integrated in this document. Apart from these general objectives, the document means to provide for the materials that will enable WP3 partners to improve the efficiency of the Work Package activities:
• The comprehensive architecture design shall enable splitting the work load according to the building blocks defined by the architecture and allocate strictly compartmented work parcels or activities to WP3 partners.
• Doing so will enable WP3 to avoid any double work
• Compartmenting the work load according to the functional building blocks as defined by the architecture will enable efficient planning of activities, be it individually or the integrated WP3 planning for the coming period, aiming at a just in time delivery of all results and products;
• Each partner that is responsible for one of the work parcels shall abide by the requirements in terms of quality and timeliness as defined by this document and prior documents and agreements made within the ITEA2 project.

## 1.3 Roles, responsibilities and tasks

In this section, the roles and responsibilities of the WP3 partners are confirmed, especially where they divert from what has been agreed upon at the start of WP3:
• First of all, in the last WP 3 meeting in Brussels on 10.09.2014 DB proposed to take over the lead of the architecture design and functional breakdown. At the subsequent weekly scrum

meeting on 12.09.2014, it was agreed upon by all participants that DB will take over the lead (see Appendix ... );
•**Planning:** Alstom as WP 3 leader will remain to be responsible for the planning and the allocation of the defined tasks to the different partners
•**Roles:** Alstom will also coordinate the work and safeguard that the defined results will be delivered according to the quality requirements that are agreed within the ITEA2 project and the schedule and the milestones that will be agreed upon during the coming workshops;
•All WP3 partners will deliver the results or products according to planning as will be agreed upon during the said workshops.

In the interest of a swift production of the critical documentation of which this version is a draft, specific tasks will be defined in terms of concrete results to be delivered, the timeframes in which these results must be produced and the partner who shall be responsible for that specific result and the planning. This is to safeguard the timely delivery. The process will be described in the next sections.

## 1.4 Process

- Alstom as WP 3 leader will be responsible for planning
- Time and quality aspects should be respected
- openETCS tools and methodology must be respected

Most of the operational requirements to WP3 in the last phases of the ITEA2 project have been described in the former paragraphs. This section will describe the process which has to lead to the final result: the reference software to be used in the demonstrator next year, more specifically the final description of the openETCS architecture including the data structures and its functional decomposition. The process will run as follows:
• DB will supervise the development of the first 'firm' draft of the specified products, 'firm' meaning that changes can only be made within the framework of these products and not to the fundamentals of these products as described in this document;
• DB will supervise the preparation of the two workshops that are proposed by Alstom and aim at defining the final and definite architecture, data structures and functional decomposition. It will make proposals for a planning of the critical tasks that remain to be done;
• Alstom will lead the two workshops following the preparations and the instructions of DB. Since all participants are intrinsically involved in the development work and tend to immerse themselves in technical discussions, for productivity purposes it is proposed to make use of a (non-technical) moderator that will be made responsible for coordinating the meeting, the discussions and the team efforts according ot the agenda.
• Also for productivity reasons, introductory presentations will be restricted to the contents and setup of this document since all prior efforts have to be merged with this document and not the other way around. Following a general introduction into the work that has been so far, the other contributions will be scrutinized on their consistency with this document and any useful sections will be merged with this document.
• During the workshops, there will be ample room reserved for enhancing this document, using other documents pertaining to the same field of work that have been delivered by other partners. Only material that is aligned with the general philosophy and structures proposed by this document, will be integrated;

• In case conflicting views emerge over the benefits and value of certain contributions, at the very moment that parties conclude that they have conflicting views, these will be listed in an inventory for later discussion. The moderator shall note any such conflicts on the said inventory. Conflicting views will be treated at the end of each workshop whenever there is sufficient time or will be treated in a separate meeting that will be chaired by DB as coordinator of the ITEA2 project.
• The workshop shall be attended by a secretary provided for by DB who is responsible for making the workshop minutes. Within a week after each workshop these minutes shall be distributed among the partners that have cooperated in the workshop and be reviewed by those.
• The main objective of the workshops shall be the finalization of this document. In order to reach the specified result, the remaining tasks shall be identified and split into separate tasks or work parcels. Every task or work parcel will be allotted to one single responsible partner. Responsibility relates to the timely delivery of the defined result and according to quality requirements;
• Alstom, as WP3 leader, will be responsible for the planning, allocation of tasks or work parcels to partners and will ensure timely delivery of results;
• In case there will be tasks or work packages that cannot be finalized during the workshops or will be identified during the workshops and do not fit in the actual planning, these will be allotted in such a way that deadlines are perfectly clear and acknowledged by the party that is responsible for the results, fit within the general requirements of the project and are agreed upon in writing and executed by the responsible partners according to agreement;
• DB as partner that has integral responsibility for both the ITEA2 project and responsible as well for the architecture etc. , is entitled to interfere take over the role as leader / coordinator in case the workshops prove to be insufficiently productive;
• All output will be such, that it can be integrated in this document. It is the responsibility of DB to integrate the results and to deliver the final and definite version of this document.
• The document concept will follow the openETCS process and tools (LaTex and Git-hub).

## 1.5 Assumption and Preconditions

- All future contributions shall be fully aligned an compliant the finalized and approved document
- Alls documents produced by the partners are requested to be compliant and merge to this document; other contributions will be discarded

The workshops are all about working as swift, as efficient and as productive as possible and make full use of the potential made available for these workshops by the partners. It is expected that the partners in the workshops will have the express intention to:
• Contribute to the workshops with the intention to finalize the openETCS architecture;
• Provide resources according to the agreements made prior to the Workshops;
• Focus primarily on getting concrete results regardless of methodological issues that might arise. Where necessary or opportune, classical project management methodology will be applied;
• Provide full transparency with respect to experience, knowledge base and information touching the subjects to be treated in the workshops;
• Document on paper or electronically all output of the workshops and integrate these with the underlying document;
• Restrict discussions only to topics that have an immediate impact on the content or the quality of the end product: the improved version of this document.

## 1.6 Functions ERTMS/ETCS

The ERTMS / ETCS system was developed with a view to interoperability of trains on the different European rail networks. It is divided into "tracks" - and "board" finishes and shall establish a mutual message operation, by beacons or through a "radio" - The transmission system (in this case a mobile telephone network GSM-R) is performed. It defines several operating levels, and the system must also interfaces with the existing monitoring systems of the trains (using STM) have. The ERTMS / ETCS system provides the transport operator (the track) the choice of conditions concerning the use and operation. The train must therefore may go with different operating conditions on routes. Thus has the onboard equipment but must be implemented, to the interoperability of the train to ensure on the other networks. These functions must therefore correspond to one standard: the system requirement specification (SRS) (version 3.3.0).

application functions, which have two different species of origin: defined in the SRS: here one finds in particular the speed monitoring- and transfer functions; these functions must be implemented in full accordance with the SRS; they can in indeed be on any network on which the train is used; these functions are described below in Section **??**;

Moreover, there are functions to adapt to the train: so, for example, the processing a "separation distance" in the airborne equipment trigger: This is dependent on the distribution of functions between the Control monitoring equipment (which the ERTMS / ETCS), and the other CCS Systems.

## 1.7 openETCS Architecture: History and Iterations

The openETCS Architecture and Design is implemented in iterations [**?** ]. The current step (second iteration) is based on a step to implement the kernel functions of the ETCS system [1]. For a better understanding of the scope the Iteration is described in the following.

### 1.7.1 First Iteration Functional Scope: The Minimum OBU Kernel Function

The openETCS first iteration architecture and the design of the openETCS OBU software as mainly specified in [2] UNISIG Subset_026 version_3.3.0.

The appropriate functionality has been divided into a list of functions of different complexity (see the WP3 function list [3]).

All these functions are object of the openETCS project and have to be analysed from their requirements and subsequently modelled and implemented. With limited manpower, a reasonable selection and order of these functions is required for the practical work that allows the distribution of the workload, more openETCS participants to join and leads to an executable—limited—kernel function as soon as possible.

While the first version of this document focuses on the first version of the limited kernel function, it is intended to grow in parallel to the growing openETCS software.

The first objective of the first iteration was

- “Make the train run as soon as possible, with a very minimum functionality, and in the form of a rapid prototype.”

This does not contradict the openETCS goal to conform to EN50128.

- After a phase of prototyping, the openETCS software shall be implemented in compliance to EN50128 for SIL4 systems.

### 1.7.2 How to find the functions of the First Iteration in the Architecture

The functions will be merged with the new architecture. Wherever a function has already been in the scope it will be marked as "first iteration".

# Glossary

| Notation | Description |
|---|---|
| application programming interface | an abstraction that is defined by the description of an interface and the behaviour of the interface. |
| balise group | One or more balises which are treated as having the same reference location on the track. |
| balise group message | |
| balise telegram | A telegram contains one header and an identified and coherent set of packets. A message maybe comprised of one or several telegrams. |
| Balise Transmission Module | On board equipment for intermittent transmission between track and train. It shall be able to receive telegrams from a balise. |
| Driver Machine Interface | ERTMS train-borne device to enable communication between ETCS and/or GSM-R and the train driver. |
| European Vital Computer | Computer device for the onboard ETCS. |
| EURORADIO | The functions required of a radio network coupled with the message protocols that provide an acceptably safe communications channel between track side and train borne equipment's |
| Juridical Recording Unit | Device to record all actions and exchanges relating to the movement of trains sufficient for off line analysis of all events leading to an incident. |
| Last Relevant Balise Group | It is the first balise group met and correctly read, when the linking information is not known by the train borne equipment. It is the last linked balise group found at the expected location and correctly read when the linking information is known by the train borne equipment. The LRBG is used as a common reference between the train borne and track side equipments in levels 2 and 3 |
| linking information | Data defining the distance between groups of balises and the action to be taken if a balise group is not detected within given limits. |

| Notation | Description |
|---|---|
| location | Location describes a position in terms of topological relations. |
| Loop Transmission Module | Train borne equipment that reads the track mounted loop data. |
| odometry | The process of measuring the train?s movement along the track. Used for speed measurement and distance measurement. |
| on-board unit | on-board equipment for ETCS and the ETCS-related GSM-R. |
| orientation | |
| radio message | The Radio Block Centre (RBC) sends electronic messages to, and receives electronic messages from, ETCS onboard equipment on trains within the area which the RBC is controlling. These messages are transmitted via GSM-R data radio |
| service brake | Train stopping, from a given speed, at such a deceleration that the passengers do not suffer discomfort or alarm or at an equivalent deceleration in the case of non-passenger trains. |
| Specific Transmission Module | The train borne equipment of the ERTMS / ETCS must be able to be interfaced with the train borne equipment of an existing train supervision system. The Specific Transmission Module shall perform a translation function between these systems and the ERTMS / ETCS. |
| system requirement specification | Specification describing the technical properties of a piece of equipment based on a corresponding functional requirement specification. |
| Systems Modeling Language | The Systems Modeling Language (SysML) is general purpose visual modeling language for systems engineering applications. SysML is defined as a dialect of the Unified Modeling Language (UML) standard, and supports the specification, analysis, design, verification and validation of a broad range of systems and systems-of-systems. These systems may include hardware, software, information, processes, personnel, and facilities. |
| Train Interface Unit | The unit that provides the interface between the train borne equipment and the train. It is likely to be unique to a class of train. |

| Notation | Description |
|---|---|
| train position | information related to the position of a train on the railway infrastructure. |

Missing Terms:
SR Staff Responsible Mode
SH Shunting Mode
RIU: Radio In-fill Unit

## 1.8 Data dictionary

**concept for the data dictionary ...**

# 2 Input Documents

See Wiki page on ....

**https://github.com/openETCS/modeling/wiki/Input-Documents-Repository**

# 3 Product Backlog

**See on:**

# 4 Architecture description (by layers)

## 4.1 Introduction to the Architecture

### 4.1.1 Abstract Hardware Architecture

For proper understanding of openETCS API and of constraints imposed on both sides of the API, we need to define a *reference abstract hardware architecture*. This hardware architecture is “abstract” is the sense that the actual vendor specific hardware architecture might be totally different of the abstract architecture described in this chapter. For example, several units might be grouped together on the same processor.

However the actual vendor specific architecture shall fulfil all the requirements and constraints of this reference abstract hardware architecture and shall not request additional constraints.

### 4.1.2 Definition of the reference abstract hardware architecture

The reference abstract hardware architecture is shown in figure 1.

The reference abstract hardware architecture is made of a bus on which are connected *units* defining the on-board unit (OBU):

- European Vital Computer (EVC);
- Train Interface Unit (TIU);
- odometry (ODO);
- DMI;
- STM;
- Balise Transmission Module (BTM);
- Loop Transmission Module (LTM): Not part of this openETCS implementation;
- EURORADIO;

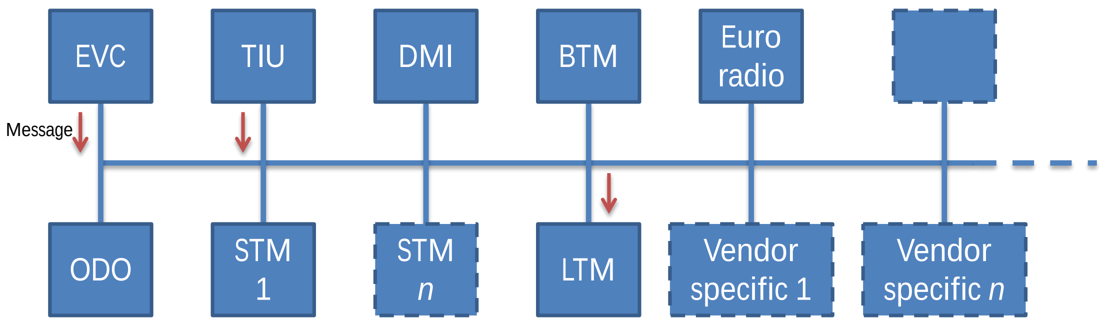


**Figure 1. Reference abstract hardware architecture**

- Juridical Recording Unit (JRU): Not part of this openETCS implementation;

Elements not being part of this implementation are marked.

Those units shall working concurrently. They shall exchange information with other units through asynchronous message passing.

#### 4.1.3 Reference abstract software architecture

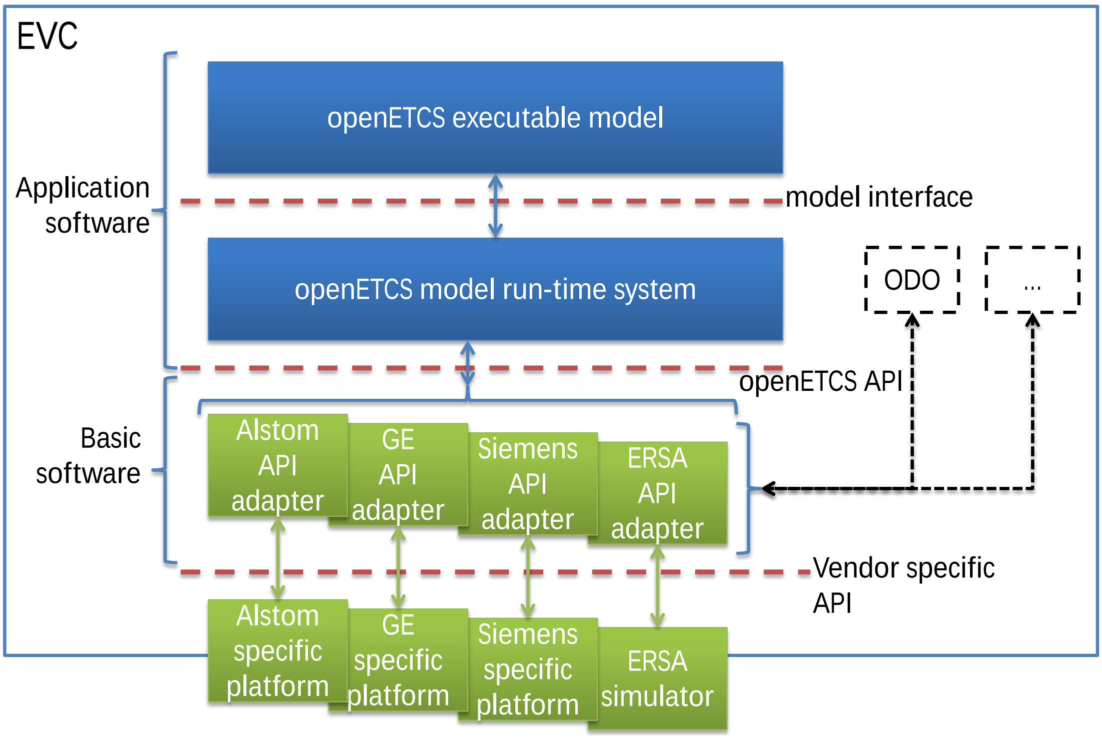


**Figure 2. Reference abstract software architecture**

The *reference abstract software architecture* is shown in figure 2. This architecture is made of following elements:

- *openETCS executable model* produced by the [4] Scade Model. It shall contain the program implementing core ETCS functions;
- *openETCS model run-time system* shall help the execution of the openETCS executable model by providing additional functions like encode/decode messages, proper execution of the model through appropriate scheduling, re-order or prioritize messages, etc.
- *Vendor specific API adapter* shall make the link between the Vendor specific platform and the openETCS model run-time system. It can buffer message parts, encode/decode messages, route messages to other EVC components, etc.
- All above three elements shall be included in the EVC;
- *Vendor specific platform* shall be all other elements of the system, bus and other units, as shown in figure 1.

We have thus three interfaces:

- *model interface* is the interface between openETCS executable model and openETCS model run-time system.
- *openETCS API* is the interface between openETCS model run-time system and Vendor specific API adapter.
- *Vendor specific API* is the interface between Vendor specific API adapter and Vendor specific platform. This interface is not publicly described for all vendors. You can find the Alstom imnplementation as an example.

The two blocks openETCS executable model and openETCS model run-time system are making the *Application software* part. This Application software might be either openETCS reference software or vendor specific software.

The Vendor specific API adapter is making the *Basic software* part.

## 4.2 Functional breakdown

### 4.2.1 F1: openETCS API Runtime System and Input to the EVC)

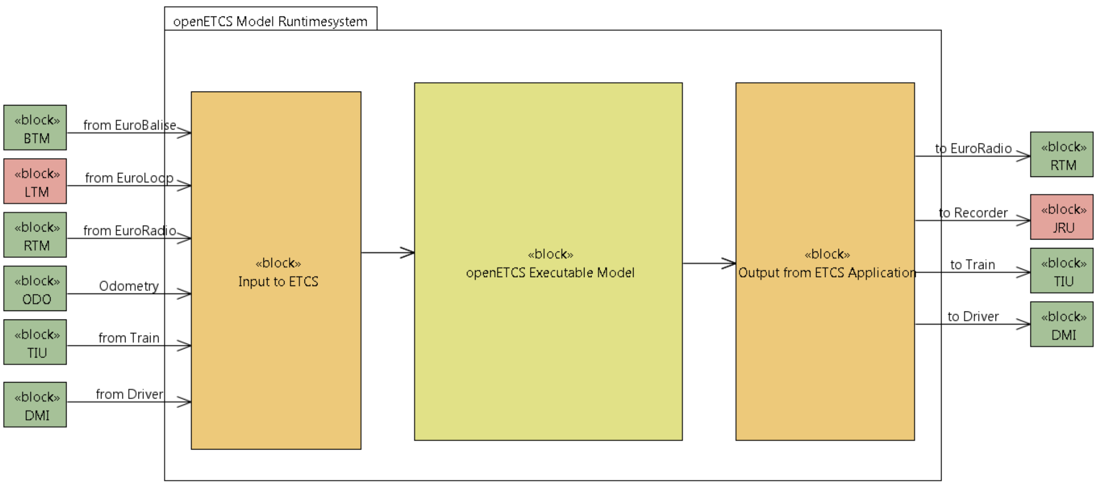


**Figure 3. openETCS API Highlevel View**

Figure 3 shows the structure of API with respect of the software architecture. Input boxes and output boxes not implemented in this stage are marked as red, other interfaces are marked as green. The System covers functions for processing Inputs from other Units, functions for processing Outputs to other functions and a basic runtime system. Inputs are used to feed the input to the executable model before calling it, outputs are used for collecting information provided by the executable model to be passed to the relevant interfaces after the execution cycle has finished.

#### 4.2.1.1 Principles for Interfaces (openETCS API)

Information is exchanged *messages* in an asynchronous way. A message is a set of information corresponding to an event of a particular unit, e.g. a balise received from the BTM. The possible kind of messages are described in chapter **??**.

The information is passed to the executable model as parmeters to the synchronous call of a procedure (Interface to the executable model). Since the availability of input messages to the application is not guaranteed the parts of the interfaces are defined with a "present" flag. In addition, fields of input arraysquite often is of variable size. Implementation in the concrete interface in this use-case is the use of a "size" parameter and a "valid"-flag.

#### 4.2.1.2 openETCS Model Runtime System

The openETCS model runtime system also provides:

- Input Functions From other Units
  In this entity messages from other connected units are received.
- Output Functions to other Units
  The entity writes messages to other connected units.
- Conversation Functions for Messages (Bitwalker)
  The conversion function are triggered by Input and Ouput Functions. The main task is to convert input messages from an bit-packed format into logical ETCS messages (the ETCS language) and Output messages from Logical into a bit-packed format. The logical format of the messages is defined for all used types in the openETCS data dictonary.
  Variable size elements in the Messages are converted to fixed length arrays with an used elements indicator.
  Optional elements are indicated with an valid flag. The conversion routines are responsible for checking the data received is valid. If faults are detected the information is passed to the openETCS executable model for further reaction.
- Model Cycle

  The version management function is part of the message handling.This implies, conversions from other physical or logical layouts of messages are mapped onto a generic format used in the EVC. Information about the origin version of the message is part of the messages.

  The executable model is called in cycles. In the cycle

  - First the received input messages are decoded
  - The input data is passed to the executable model in a predefined order. **(Details for the interface to be defined)**.
  - Output is encoded according to the SRS and passed to the buffers to the units.

#### 4.2.1.3 Input Interfaces of the openETCS API From other Units of the OBU

Interfaces are defined in the Scade project APITypes (package API_Msg_Pkg.xscade).

In the interfaces the following principles for indicating the quality of the information is used:

| Indicator | Type | Purpose |
|---|---|---|
| present | bool | True indicates the component has been changed compared to the previous call of the routine |
| valid | bool | True indicates the component is valid to be used. |
| validated | bool | True indicates the component has been validated. |

In the next table we can see the interfaces being used in the openETCS system. Details on the interfaces are defined further down.

| Unit | Name | Processing Function | Description |
|---|---|---|---|
| BTM | Balise Telegram | Receive Messages | |
| DMI | | | |
| EURORADIO | Communication Management | Communication Management | |
| EURORADIO | Radio Messages | Receive Messages | |
| ODO | Odometer | All Parts | |
| TIME | Time system of the OBU | All Parts | |
| Startup | | | |
| TIU | Train Data | All Parts | |

Infrmation in the following sections gives an more detailed overview of the structure of the interfaces.

#### 4.2.1.4 Message based interface (BTM, RTM)

Balise Message (Track to Train)

| Message Name | Optional Packets | Restrictions in the current scope |
|---|---|---|
| Balise Telegram | 3: National Values<br>41: Level Transition Order<br>42: Session Management<br>45: Radio Network registration<br>46: Conditional Level Transition Order<br>65: Temporary Speed Restriction<br>72: Packet for sending plain text messages<br>137: Stop if in Staff Responsible<br>255: End of Information | Used in Scenario |

| | | |
|---|---|---|
| Balise Telegram | 0, 2, 3, 5, 6, 12, 16, 21, 27, 39, 40, 41, 42, 44, 45, 46, 49, 51, 52, 65, 66, 67, 68, 69, 70, 71, 72, 76, 79, 80, 88, 90, 131, 132, 133, 134, 135, 136, 137, 138, 139, 141, 145, 180, 181, 254 | Not Used in Scenario |

Radio Messages (Track to Train)

| Message Name | Optional Packets | Restrictions in the current scope |
|---|---|---|
| 2: SR Authorisation | 63: List of Balises in SR Authority | Message Not Supported |
| 3: Movement Authority | 21: Gradient Profile<br>27: International Static Speed Profile<br>49: List of balises for SH Area<br>80: Mode profile<br>plus common optional packets | a |
| 9: Request To Shorten MA | 49: List of balises for SH Area<br>80: Mode profile | |
| 24: General Message | From RBC:<br>21: Gradient Profile<br>27: International Static Speed Profile<br>plus common optional packets<br>From RIU:<br>44, 45, 143, 180, 254 | Messages from RIU are not supported |
| 28: SH authorised | 3, 44, 49 | |
| 33: MA with Shifted Location Reference | 21: Gradient Profile<br>27: International Static Speed Profile<br>49: List of balises for SH Area<br>80: Mode profile<br>plus common optional packets | |
| 37: Infill MA | 5, 21, 27, 39, 40, 41, 44, 49, 51, 52, 65, 66, 68, 69, 70, 71, 80, 88, 138, 139 | Message Not Supported |
| List of common optional parameters | 3, 5, 39, 40, 51, 41, 42, 44, 45, 52, 57, 58, 64, 65, 66, 68, 69, 70, 71, 72, 76, 79, 88, 131, 138, 139, 140, 180 | |

#### 4.2.1.5 Interfaces to the Time System

The interface types are defined in the OBU_Basic_Types_Pkg Package. The system time is defined in the basic software.

The system TIME is provided to the executable model at the begin of the cycle. It is not refreshed during the cycle. The time provided to the application is equal to 0 at power-up of the EVC (it is not a “UTC time” nor a “Local Time”), then must increase at each cycle (unit = 1 msec), until it reaches its maximum value (i.e current EVC limitation = 24 hours)

- TIME (T_internal_Type, 32-bit INT)
  Standardized system time type used for all internal time calculations: in ms. The time is defined as a cyclic counter: When the maximum is exceeded the time starts from 0 again.

#### 4.2.1.6 Interfaces to the Odometry System

The interface types are defined in the OBU_Basic_Types_Pkg Package. The odometer gives the current information of the positing system of the train. In this section the structure of the interfaces are only highlighted. Details, including the internal definitions for distances, locations speed and time are implemented in the package.

- Odometer (odometry_T)
  - valid (bool)
    valid flag, i.e., the information is provided by the ODO system and can be used.
  - timestamp (T_internal_Type)
    of the system when the odometer information was collected. Please, see also general remarks on the time system.
  - Coordinate (odometryLocation_T)
    * nominal (L_internal_Type) [cm]
    * min (L_internal_Type) [cm]
    * max (L_internal_Type) [cm]

    The type used for length values is a 32 bit integer. Min and max value give the interval where the train is to be expected. The bounderies are determined by the inaccuracy of the positioning system. All values are set to 0 when the train starts.
  - speed (V_internal_Type) [km/h] General Speed of the train
  - acceleration (A_internal_Type)[0.01 m/s2],
    Standardized acceleration type for all internal calculations : in
  - motionState (Enumeration)
    indicates whether the train is in motion or in no motion
  - motionDirection (Enumeration)
    indicates the direction of the train, i.e., CAB-A first, CAB-B first or unknown.

#### 4.2.1.7 Interfaces to the Train Interfaces (TIU)

The following infomration is based on the implementation of the Alstom API. The interface is organised in packets. The packets of the Alstom implementation are listed in the appendix to this document.

The description of interfaces needed for the current scope will be added according to the use.

#### 4.2.1.8 Output Interfaces of the openETCS API TO other Units of the OBU

| From Function | Name | To Unit | Description |
|---|---|---|---|
| | Radio Output Message | EURORADIO | |

| | | | |
|---|---|---|---|
| | Communication Management | EURORADIO | |
| | Driver Information | DMI | |
| | Train Data | TIU | |

Packets: to be completed

Radio Messages to be completed

#### 4.2.2 F2: Receive messages / check consistency

fixme Picture missing: IBD

##### 4.2.2.1 Short Description of Functionality

The block "Receive messages / check consistency" is responsible for receiving Eurobalise-telegrams and Euroradio-messages from the API and perform several consistency checks on the input.

The block collects the telegrams of balises in order to build balise group messages. Euroradio messages are always delivered as a whole message. After receiving, building and checking a message, the message is delivered to the output of the module for further processing by other modules.

##### 4.2.2.2 Input

Note: Only radio functionality covered!

For providing the output, the module needs different input data flows. An overview is provided in table 2

| Index | Input name | Input type |
|---|---|---|
| 0 | `rtmMessage` | `< will be defined by API >` |
| 1 | `radioDevice` | `int` |
| 2 | `apiConsistencyError` | `bool` |
| 3 | `lastRelevantEventTimestamp` | `T_internal_Type` |
| 4 | `t_NVContact` | `T_internal_Type` |
| 5 | `reset` | `bool` |

**Table 2. Overview over input**

**Input 0: `rtmMessage`**

The Euroradio-/Eurobalise-message is originated from the openETCS-API. The API is described in the section 4.2.1.

In the current implementation, only messages with normal priority are used in the system. Emergency messages will not be processed.

In the model, the output of the API will be received at the inputs `rtmMessage` and `apiConsistencyError` of the model.

The input not only transfers the radio message but also information, if a message is present and if this message was decoded correctly and passed the lowlevel checks performed by the API.

The radio message itself consists of a header and a payload-part. The header part contains all variables of the message. The payload-part consists of all packets in the message.

For the demonstrator scenario (Utrecht-Amsterdam), the following messages and packets are to be expected by the model:

- Messages from RBC: 2, 3, 6, 8, 15, 24, 27, 32, 39, 41
- Packets from RBC: 3, 5, 15, 21, 27, 41, 42, 57, 58, 65, 68, 72, 80

#### Short Description of Functionality

"ManageBaliseInformation" manages information related to balise telegrams received via the API when the train passes a balise. Balise telegrams are collected to build balise group messages. Finally, the message is checked for consistency, the train direction is calculated and the balise group message is passed to the other functions.

Information of the odometer is used to control for the train leaving the expectation window of the balises.

#### Input

- reset (bool) Request a reset of the data in the function. If reset=true no other input to the model is valid.
- API Telegram
  The telegram is build from
  - a present flag (bool)
    Indicates the input decoded telegram parameter is “present”, i.e., the input has been updated by the API. Only if the telegram is present the position information (incenterOfBalise) is to be used.
  - the decoded telegram including optional packets received from the balise.
  - the centerOfBalisePosition parameter. This parameter is used to give the position where the BTM has recognised the center of the balise telegram.
- inActualOdometry
  Actual Information giving the odometry of the train.
- LRBG
  The Last Relevant Balise Group. The information has been collected before by the train position function.

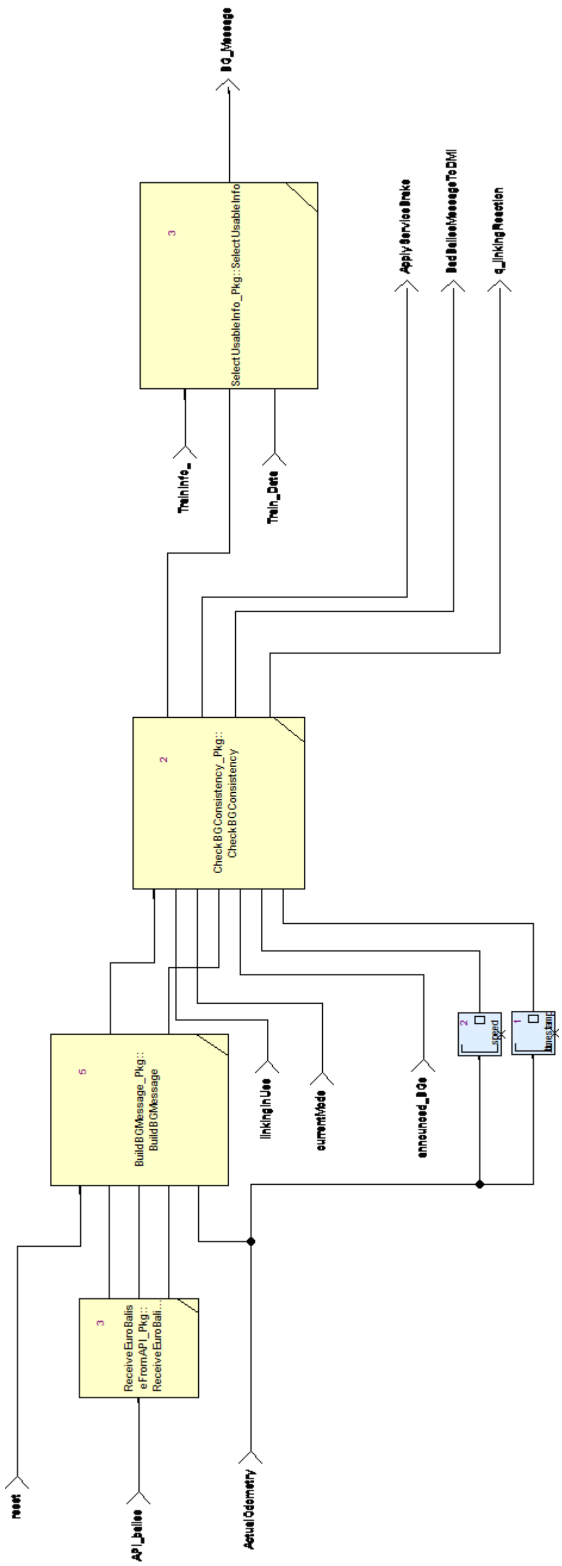


**Figure 4. Structure of Manage Balise Information Block**

### Output

- BG-Message
  Information describing the actual balise group just received.
- ApplyServiceBreak
  The flag indicates the balise group the train just passed could not be processed correctly. The check results in the request for a service break.
- BadBaliseMessageToDMI
  Information to be passed to the DMI to indicate the reception of a "bad balise" to the driver.

### Data

- The function makes use of internal data for collecting and checking the balise telegrams.

### Reference to the SRS (or other requirements)

- Definition of the Balise Telegram: subset 26 section 7 and 8
- Interface to the BTM: Subset 36, section 4.2.2, 4.2.4, 4.2.9
- Handling of Balise Telegrams: Subset 26, sections 3.4.1 - 3.4.3, 3.16.2
- Check of the balise group Subset 26, section 3.16.2
- Determining the Orientation: 3.4.2

### Design Constraints and Choices

### 4.2.2.3 F.1.1 Receive Eurobalise From API

### Short Description of Functionality

This function defines the interface of the OBU model to the openETCS generic API for Eurobalise Messages. On the interface, either a valid telegram is provided or a telegram is indicated which could not be received correct when passing the balise. The function passes the telegram without major changes of the information to the next entity for collecting the balise group information.

### Reference to the SRS (or other requirements)

- Definition of the Balise Telegram: subset 26 section 7 and 8
- Interface to the BTM: Subset 36, section 4.2.2, 4.2.4, 4.2.9

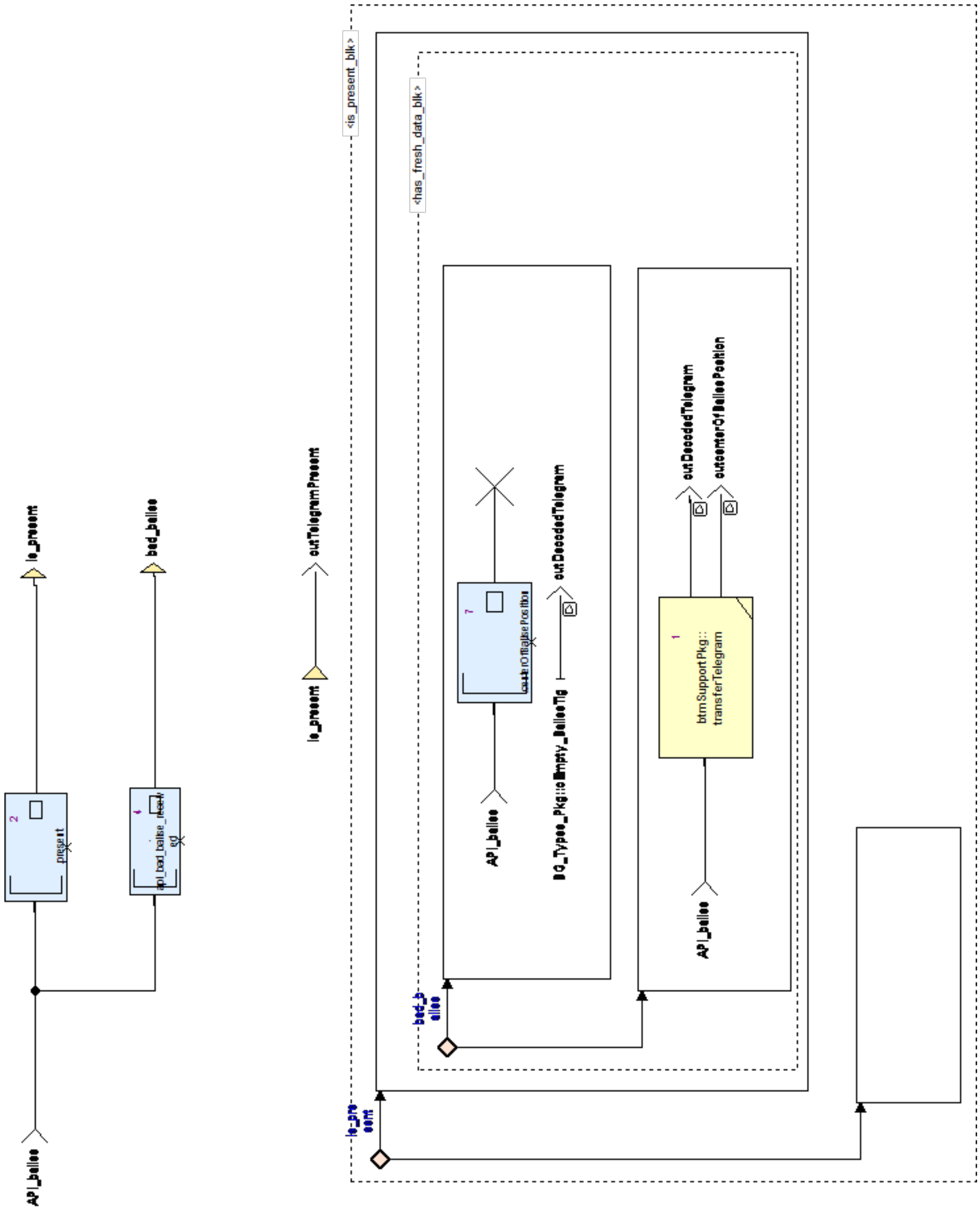

Figure 5. Structure of ReceiveEuroBaliseFromAPI

#### Design Constraints and Choices

1. The decoding of balises is done at the API. Also, packets received via the interface are already transformed into a usable shape.
2. Only packets used inside the current model are passed via the interface:
   Packet 5: Linking Information.
   Linking Information is added to the linking array starting from index 0 without gaps. Used elements are marked as valid. Elements are sorted according to the order given by the telegram sequence.

### 4.2.2.4 F.1.2 Build BG Group Message

#### Short Description of Functionality

This entity collects telegrams received via the interface into Balise Group Information.

#### Reference to the SRS (or other requirements)

- Interface to the BTM: Subset 36, section 4.2.2, 4.2.4, 4.2.9
- Handling of Balise Telegrams: Subset 26, sections 3.4.1 - 3.4.3, 3.16.2

#### Design Constraints and Choices

1. Telegrams received as invalid are passed to the “Check-Function” to process errors in communication with the track side according to the requirements and in a single place. Telegrams are added to the telegram array starting from index 0 without gaps. Used elements are marked as valid. Elements are stored according to the order given by the telegram sequence.
2. This function does not process information from the packets. The information is passed to the check without further processing of the values.

### 4.2.2.5 F.1.3 Check BG Consistency

#### Short Description of Functionality

This function has the task to verify the completeness and correctness of the received messages from balis-groups.
A message consists of at least a telegram and a maximum of 8 telegrams.

- A message is still complete and correct, if a telegram is missing (or not decoded or incomplete decoded ), and this telegram is duplicated within the balise group and the duplicating one is correctly read.

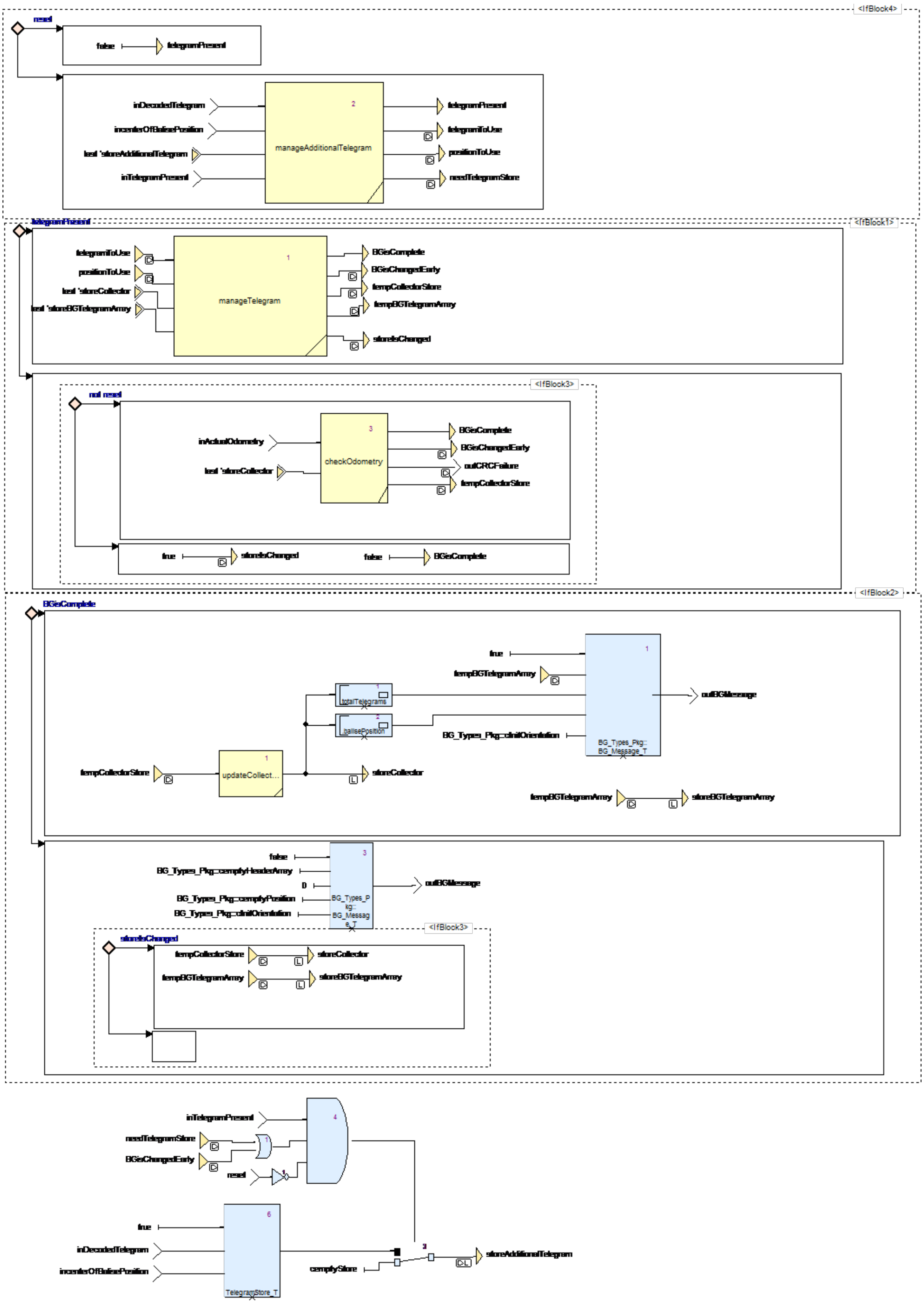

Figure 6. Structure of BuildBGMessage

- By more than one telegram, the order of the telegrams must be either ascending (nominal ) or Descending(reverse).

- A message is correct, if all message counters (M MCUNT) do not equal 254 (that means: The telegram never fits any message of the group).
  A message counter can be equal 255 (that means: The telegram fits with all telegrams of the same balise group) and all other values must be the same.

For a correct balise group the balise group message is generated and passed to the system. In error situations the triggers for the driver and the breaking system are generated. I

#### Reference to the SRS (or other requirements)

- Check of the balise group Subset 26, section 3.16.2

- Determining the Orientation: 3.4.2

- Active Functions Table: 4.5.2

#### Design Constraints and Choices

This function is active in certain modes and the output and reactions are dependent on if the linking information is used.
The orientation of the BG will also be calculated in this block. The check, if the message has been received in due time and the right at the right expected location, will be performed in "Calculate Train Position".
The checks on the validity of the data in the packets and the validity with respect to the direction of motion will be performed in other modules, e.g. "Validate Data Direction" .

#### Input 1: `radioDevice`

The RTM-module can consist of multiple radio devices. When a handover between two RBCs is performed, messages can be received from both radio devices. The API provides information about the device, which received the message.

The values transmitted have to be defined by the API.

#### Input 2: `apiConsistencyError`

If the API detects a consistency error in the transmitted message, this error is reported to the model by the input `apiConsistencyError`.

Possible errors detectable by the API are:

- CRC-error

- Value range of variable exceeded

| Value | Interpretation |
|---|---|
| true | The API detected a consistency error. |
| false | No consistency error was detected by the API. |

**Table 3. Possible values for the input `apiConsistencyError`**

#### Input 3: `lastRelevantEventTimestamp`

For monitoring the safe radio connection, it's necessary, that the time between two packets is less than the value of `T_NVCONTACT`.

In situations like level-changes or announced radioholes, not the timestamp of the last message is relevant for comparison, but the timestamp of the last relevant event. This can be e.g. the timestamp of the level change or the timestamp of the timestamp of the moment, when the train was passing the end of the radiohole.

For performing this check, the timestamp of the last relevant event is provided to the model as an `T_internal_Type`-type.

#### Input 4: `t_NVContact`

For monitoring the safe radio connection, the national value `T_NVCONTACT` is needed as an input.

#### Input 5: `reset`

To delete all data stored in the module (e.g. collected balise-telegrams, which do not yet form a complete message), a reset input can be used. If the input is set to `true`, all data kept in the module is deleted and no input is accepted.

| Value | Interpretation |
|---|---|
| true | All data kept in the module is deleted and no input is accepted. |
| false | No action. Data at input is accepted. |

**Table 4. Possible values for the input `reset`**

#### Output

Note: Only radio functionality covered

The output of the module provides the received and processed Euroradio and Eurobalise messages. The module combines messages both from Eurobalises and from Euroradio to one common dataflow.

Additionally, status information is provided. The status information consists of the following data:

- Information, if the message has to be rejected in case of a consistency error, includeing further information about the error.
- Information, if an acknowledgement has to be sent to the RBC for the message
- Information about the radio connection. None or one of the following notifications:
  - Confirmation for establishing a connection or reconnection
  - Notification, that a established connection was lost, including the origin of the failure
  - Notification, that a connection could not be (re)established after 3 attempts, includeing the origin of the failure
  - Notification, that a connection could not be re-established after 3 attempts, includeing the origin of the failure

An overview over the output dataflows is provided in table **??**.

| Index | Output name | Output type |
|---|---|---|
| 0 | `valid` | `bool` |
| 1 | `rejectionReason` | Boolean-Array (to be defined) |
| 2 | `acknowledgementRequired` | `bool` |
| 3 | `radioConnectionStatus` | `Enumeration` |
| 4 | `radioDeviceOut` | `int` |
| 5 | `receivedMessage` | `receivedMessage_T` |

**Table 5. Fields of the `checkedRadioMessage_T`-type**

**Output 0: `valid`** The valid-flag specifies, if the data provided by the output `receivedMessage` is valid or if it was rejected.

Invalid data can be recognized either by the API (e.g. CRC-check) or by the consistency check in this module.

| Value | Interpretation |
|---|---|
| false | The data in this element is not valid and has to be rejected. |
| true | The data in this element is valid and has to be processed by the following models. |

**Table 6. Possible values for the output `valid`**

**Output 1: `rejectedReason`** In case of an inconsistent message, the output `rejectedReason` is giving information to the system, which problem occured. This information also has to be sent to the RBC as an error report.

**Output 2: `acknowledgementRequired`** The `acknowledgementRequired`-dataflow indicates, whether the reception of the message has to be acknowledged to the RBC.

| Value | Interpretation |
|---|---|
| true | An acknowledgement has to be sent to the RBC for the current message delivered at output `receivedMessage` |
| false | No acknowledgement has to be sent for the current message delivered at output `receivedMessage` |

**Table 7. Possible values for the output `AcknowledgementRequired`**

**Output 3: `radioConnectionStatus`** The output ConnectionStatus is used, when the RTM reports problems with the radio connection. The output is derived from the Alstom-API. The output can be one of the following values:

| Value | Interpretation |
|---|---|
| CONNECTION_CONFIRMATION | Confirmation for establishing a connection or reconnection |
| CONNECTION_LOST | Notification, that a established connection was lost |
| CONNECTION_FAILURE | Notification, that a connection could not be (re-)established after 3 attempts, includeing the origin of the failure |
| CONNECTION_NOT_ESTABLISHED | Notification, that a connection could not be re-established after 3 attempts, includeing the origin of the failure |

**Table 8. Possible values for the output `radioConnectionStatus`**

**Output 4: `radioDeviceOut`** The output radio device will give information, which device received a radio message. Trains equipped with two or more radio devices may receive messages on two interfaces in situations of a RBC handover.

**Output 5: `receivedMessage`** The element `receivedMessage` consists of the type `receivedMessage_T` combines both balise and radio messages to one common datatype. This datatype contains all variables and packets, which are possible for the given scenario.

| Name | Datatype | Description |
|---|---|---|
| source | Enumeration | Defines, if this is a Euroradio or Eurobalise message. |
| BG_Common_Header | `BG_Header_T` | Header of Eurobalise message |
| Radio_Common_Header | `Radio_TrackTrain_Header_T` | Header of Euroradio message |
| Packets | structure of possible packets | - |

**Table 9. Structure of `receivedMessage_T`**

The Eurobalise-common-header `BG_Header_T` consists of the fields described in table 10. The structure corresponds to the structure defined in the SRS chapter 8.4.2.1. Some fields were removed since they are not needed anymore for further processing after building messages from separate telegrams.

| Name | Datatype | Origin |
|---|---|---|
| q_updown | Q_UPDOWN | Eurobalise-Header |
| m_version | M_VERSION | Eurobalise-Header |
| q_media | Q_MEDIA | Eurobalise-Header |
| n_total | N_TOTAL | Eurobalise-Header |
| m_mcount | M_MCOUNT | Eurobalise-Header |
| nid_c | NID_C | Eurobalise-Header |
| nid_bg | NID_BG | Eurobalise-Header |
| q_link | Q_LINK | Eurobalise-Header |

**Table 10. Structure of `BG_Header_T`**

The Euroradio-common-header `Radio_TrackTrain_Header_T` consists of the fields described in table 11. The structure corresponds to the structure defined in the SRS chapter 8.4.4.6.1. The structure contains all variables required by possible `NID_MESSAGE` values for the given scenario.

| Name | Datatype | Origin |
|---|---|---|
| nid_message | NID_MESSAGE | Euroradio-Header |
| t_train | T_TRAIN | Euroradio-Header |
| m_ack | M_ACK | Euroradio-Header |
| nid_lrbg | NID_LRBG | Euroradio-Header |
| q_scale | Q_SCALE | Messages 2, 33 |
| d_sr | D_SR | Message 2 |
| t_sh_rqst | T_TRAIN | Message 28 |
| d_ref | D_REF | Message 33 |

**Table 11. Structure of `Radio_TrackTrain_Header_T`**

**Note:** Packet 44 not used (applications outside the ERTMS/ETCS system are not supported by this implementation).

### Data

The timestamp of the last received message via Euroradio has to be stored in an internal data structure.

An internal data structure to temporarily store balise telegrams for building messages is needed.

### Reference to the SRS (or other requirements)

| Note: Only radio functionality covered |
|---|

### Euroradio

- SRS subset 26, chapter 8.4.4: Rules for Euroradio messages

- SRS subset 26, chapter 3.16: Data consistency

### Functionality

| Note: Only radio functionality covered for checks |
|---|

**Receive Euroradio from API** The first stage of the module is the reception of Euroradio-messages and Eurobalise-Telegrams from the openETCS-API. At each cycle the following conditions can occur:

1. No new Euroradio-message or Eurobalise-telegram is available.
2. A new Euroradio-message is available
3. A new Eurobalise-telegram is available
4. A new Euroradio-message and a new Eurobalise-telegram is available.

### Content checks

- The whole message must be complete and contains all necessary fields. (SRS 8.16.1.1)
- The message must respect the ETCS language. (SRS 8.16.1.1)
- The variables of the message does not contain invalid values. (SRS 8.16.1.1)
- Check if the specified priority of message is equal to the priority with which the message was received. (SRS 3.16.3.1.3.1)

### Timing checks

- Check if the timestamp of a message is greater than the timestamp of the former message (SRS 3.16.3.3.3)
- If a message contains the timestamp “Unknown”, check if this message is part of the initiation of the communication session. (SRS 3.16.3.3.4)
- Perform the check with the current packet $n$: $T\_TRAIN_n <= T\_TRAIN_{n-1} + T\_NVCONTACT$ (SRS 3.16.1.1). This ensures, that the packet was received in due time.

### Actions for inconsistent messages

- If a message is not consistent, it shall be rejected (SRS 3.16.3.1.1.1). For this purpose, the message is marked as invalid.
- The RBC shall be informed, when a message was rejected (SRS 3.16.3.1.1.2). Therefore the message is marked with necessary information for creating an error report.

- If the RBC requested an ACK for a received message, message will be marked for the module to send a report to the RBC. (SRS 3.16.3.5)
- This module will not trigger the reaction for an interrupted radio connection to the RBC. The reaction sepcified by `M_NVCONTACT` will be triggered by the RBC session management module.

#### Other functionality

- The module will only output a maximum of one message per cycle. The module will take care of buffering other messages until they will be delivered at the output.

The check by the Euroradio-protocol (3.16.3.1.1) will not be performed by the model, but on a lower level (RTM or openETCS-API).

Safe connection supervision is not in the scope of this module. This functionality will be implemented by the “Manage Radio communication” module. The “Receive message and check consistency”-module will provide the necessary status data about the connection as an output.

#### 4.2.2.6 F.2.1 Validate Data Direction

#### Short Description of Functionality

This function determines for direction information of the LRBG or an (ordinary) balise group whether this information is valid or not. The function takes as an input the LRBG and the balise groups passed and outputs the input extended with validity information.

#### Reference to the SRS (or other requirements

The functionality is mainly described in [2, Chapter 3.6.3].

#### Design Constraints and Choices

none

### 4.2.3 F.1.5 Select Usable Info - Mode and Level Filter

#### Short Description of Functionality

The function Select Usable Info filters information received from balises that have been passed, radio messages, and EUROLOOP messages. Filtering is done depending on the mode of the train, the current ETCS level, the type/content of the information, and the transition media of the information. As neither radio messages nor EUROLOOP are part of the first iteration of work, not all functionality of the filter described in the specification is currently implemented.

#### Reference to the SRS (or other requirements)

The functionality of Select Usable Info is described in Chapter 4.8 of subset-026 [2]. The following list gives an overview of the most important sections for each of the blocks in the model.

**First filter** The first filter, i.e. the filter on the level, is described in [2, Chapter 4.8.3].

**Second filter** The second filter, i.e. the filter on the transition media, is described in[2, Chapter 4.8.3].

**Third filter** The third filter, i.e. the filter on the modes, is described in [2, Chapter 4.8.4].

**Transition buffers** Details on the handling of the transition buffers used in the first and the second filter are described in [2, Chapter 4.8.5].

#### Design Constraints and Choices

The first iteration of the model takes only balise group messages into account. This implies that a large part of the specification of this function described in subset-026 [2] is not relevant for the first iteration. This in particular applies to the second filter, i.e. filter on the transition media, because radio messages are not part of the model so far. Moreover, the functionality of the first filter, i.e. filter on the level, is currently limited because the first iteration of the model implements ETCS level 1 only.

#### Filtering (Mode/Level) - One packet per type

**ISSUE: HOW MANY PKT 44, 65 AND 66 PER MESSAGE ARE MAXIMALLY SUPPORTED? (BH: who made this comment??)**

- Check on announced and immediate level transition orders in the messages to be filtered (needed for further criteria for filtering, to decide if the data shall be stored in the transition buffer).
- Filter data stored in the transition buffer according to the current level (what to do if similar information is available in the new message??). Data can be rejected, accepted or kept in the transition buffer. (Filtering according to new level will be done directly afterwards in the next cycle)
- Filter new received messages according to the current level (new level will be done in the next cycle as according to SRS data first has to be filtered according to old level and afterwards to new level). Data can be rejected, accepted or stored in the transition buffer.
- Filter (level) accepted data according to originating RBC (supervising or other). Information from BG's, loops or RIU is not filtered with this filter.
- Filter (level and RBC) accepted data according to the current mode (only reject or accept)

### 4.2.4 Build coordinate system and calculate train position

- Update the coordinate system when a new BG is detected (taking into account detected "balise 1" from not completed BG's), i.e. backward - - Calculation of position of passed BG's.
- Management of multiple detected BG's
- Relate the (location based) information in received messages to the reference system
- Update train position at LRBG
- Update the train position with the distance driven since last update (or reset to LRBG position)

### 4.2.5 F.2.2 Calculate Train Position

#### 4.2.5.1 Short Description of Functionality

The main purpose of the function is to calculate the locations of linked and unlinked balise groups (BGs) and the current train position while the train is running along the track.

#### Functional Structure in Stages

The function calculateTrainPosition is divided into the following four functions, which are being performed sequentially:

1. ***calculateBGLocations***: Calculate the balise group locations
   The first stage is triggered each time the train passes a balise group (input *passedBG*). It takes the balise group header with the BG identification, the linking information (Subset 26, packet 5) and the current odometry values as inputs and calculates the location of the the passed balise group. If the passed BG has been announced via linking information previously, it takes into account the linking as well as the odometry information. If the passed BG does not meet the tolerance window announced by linking, an error flag is set. If the passed BG is an unlinked BG, its location is determined by odometry only, but related to the next previously passed linked BG, if there is one.
   Then, if the passed BG is a linked BG comprising linking information for BGs ahead, the linking information is evaluated by creating the announced BGs and computing their locations from the linking distances.
   The passed and the announced BGs are stored in a list *BGs*, ordered by their nominal location on the track.
   Afterwards the locations of all BGs are further improved by re-adjusting their locations with reference to the just passed BG. This optimizes the BG location inaccuries around the current train position (= location of the passed BG).

2. ***delDispensableBGs***: Delete dispensable balise groups
   The second stage removes balise groups supposed not to be needed any longer from the list of *BGs*.
   If the number of stored passed linked BGs exceeds the maximum number of eight as specified in [2, Chapter 3.6.2.2.2 c], all BGs astern are deleted. If only (passed) unlinked BGs are in the list and exceed the number of *cNoOfAtLeast_x_unlinkedBGs*, all passed BGs astern to those are removed from the list.

3. ***calculateTrainPositionInfo***: Calculate train position information.
   This stage take the list of stored BGs and the current odometry values as inputs and steadily provides the current train position.

4. ***calculateTrainpositionAttributes***: Calculate train position attribute information.
   This stage provides several additional position related attributes that might conveniently be used by subsequent consumers in the architecture. It requires the actual LRBG and the previous LRBG to be assigned external from the list *BGs*.

#### 4.2.5.2 Reference to the SRS (or other requirements)

The component calculateTrainPosition determines the location of linked and unlinked balise groups and the current train position during the train trip as specified mainly in [2, Chapter 3.6].

#### 4.2.5.3 Design Constraints and Choices

The following constraints and prerequisites apply:

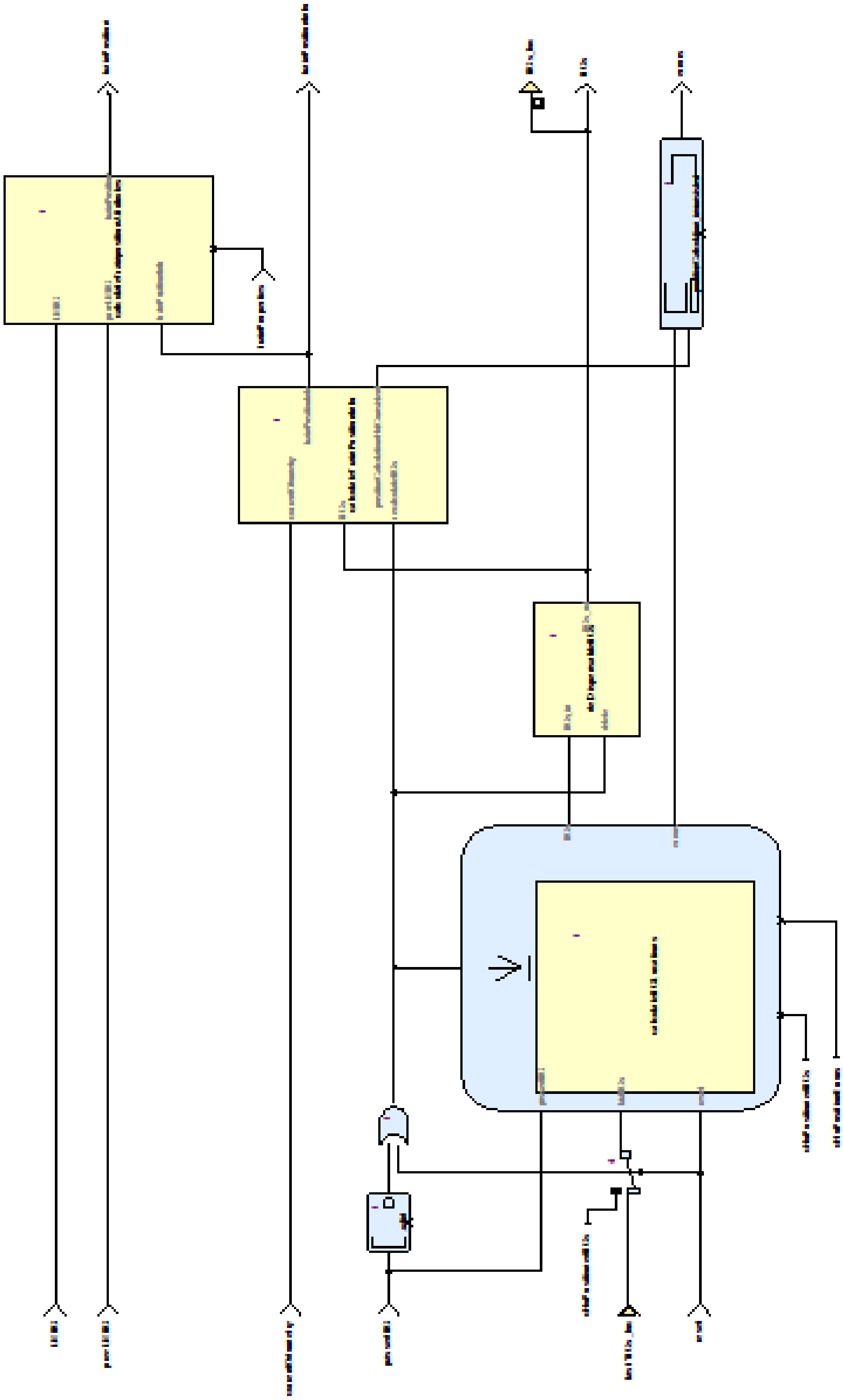

Figure 7. Structure of calculateTrainPosition

1. The input data received from the balises groups must have been checked and filtered for validity, consistency and the appropriate train orientation before delivering them to calculate-TrainPosition.
2. The storage capacity for balise groups is finite. calculateTrainPosition will raise an error flag when a balise group cannot be stored due to capacity limitations.
3. calculateTrainPosition will raise an error flag if a just passed balise group is not found where announced by linking information. It will not (yet) detect when an announced balise group is missing.
4. calculateTrainPosition is not yet prepared for train movement direction changes.
5. calculateTrainPosition does not yet consider repositioning information.

### 4.2.6 Provide Position Report

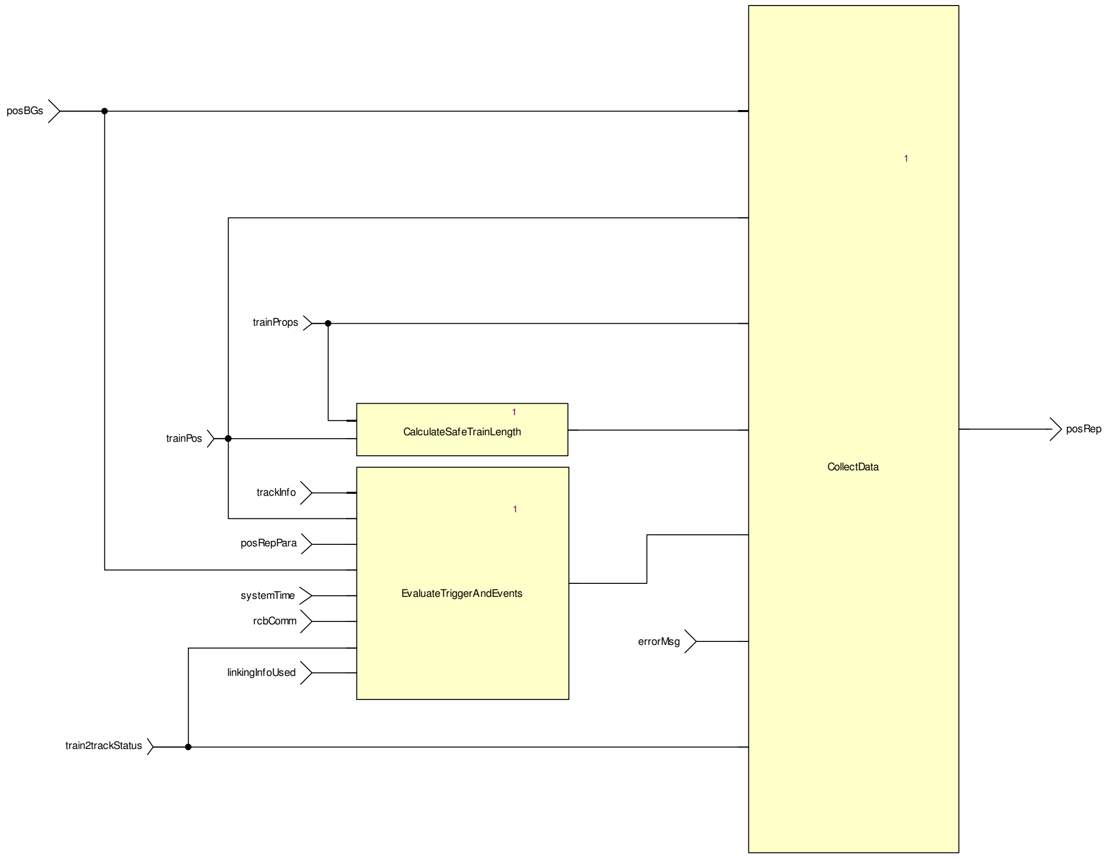


**Figure 8. Structure of component ProvidePositionReport**

#### 4.2.6.1 Short Description of Functionality

This function takes the current train position and generates a position report which is sent to the RBC. The point in time when such a report is sent is determined by events, on the one hand, and position report parameters—which are basically triggers—provided by the RBC or a balise group passed, on the other hand. The functionality is modeled using three operations, as shown in Figure 8, which are explained below.

**CalculateSafeTrainLength** Calculates the the safeTrainLength and the MinSafeRearEnd according to [2, Chapter 3.6.5.2.4/5].

`safeTrainLength = absolute(EstimatedFrontEndPosition - MinSafeRearEnd)`, where `MinSafeRearEnd = minSafeFrontEndPosition - L_TRAIN`.

**EvaluateTriggerAndEvents** Returns a Boolean modelling whether the sending of the next position report is triggered or not. This value is the conjunction of the evaluation of all triggers (PositionReportParameters, i.e., Packet 58) and events (see [2, Chapter 3.6.5.1.4]).

**CollectData** This operation aggregates data of Packet 0, ..., Packet 5 and the header to a position report.

#### 4.2.6.2 Reference to the SRS (or other requirements

Most of the functionality is described in [2, Chapter 3.6.5].

#### 4.2.6.3 Design Constraints and Choices

1. The message length (i.e., attribute `L_MESSAGE`) is by default set to 0; the actual value will be set by the Bitwalker/API.
2. The attribute `Q_SCALE` is assumed to be constant; that is, all operations using this attribute do not convert between different values of that attribute.
3. *PositionReportHeader*: The time stamp (i.e., attribute `T_TRAIN`) is not set; this should be done once the message is being sent by the API.
4. *Packet 4*: When aggregating data for this packet, an error message might be overwritten by a succeeding error message. Because the specification allows only to sent one error in one position report, errors are not being stored in a queue, for instance.
5. *Packet 44*: This packet is currently not contained in a position report as it is not part of the kernel functions.
6. The usage of attributes `D_CYCLOC` and `T_CYCLOC` as part of the triggers specified by the position report parameters (i.e., Packet 58 sent by the RBC) may lead to unexpected results if a big clock cycle together with small values for the attributes is used. The cause is that at every clock cycle the current model increments the reference value for the distance and time by at most `D_CYCLOC` and `T_CYCLOC`, respectively and not a factor of it.

#### 4.2.6.4 Open Issues

1. The specification requires to store the last eight balise groups for which a position report has been sent (see [2, Chapter 3.6.2.2.2.c]).
2. For all reports that contain Packet 1 (i.e., report based on two balise groups), the RBC sends a coordinate system. It is unclear where this has to be stored (i.e., somehow the balise groups have to be stored in a database which has then to be updated), see [2, Chapter 3.4.2.3.3.6]. Moreover, such a coordination system can be invalid and then has to be rejected (see [2, Chapter 3.4.2.3.3.7-8]). On a more abstract level, we need to think about the interface between the RBC and the OBU or a proper abstraction thereof.

#### 4.2.7 Store inputs from the TIU

- Store status inputs (sleeping indicator etc.)
- Store changed train data
- Store brake status (e.g. in the handling of brake testing).
- Store status of on-board systems (for displaying to the driver)
- Isolation
- Passive shunting

#### 4.2.8 Store inputs from the DMI

- Store received acknowledgement and inputs in the "DMI request buffer" (includes "data-entry")

#### 4.2.9 Store data (direct orders, BG lists, NV, track data, procedure parameters, confirmations)

- Store direct and conditional orders
- Store BG lists for SH and SR
- Store National Values, including procedure status information
- Store new received track data (version, etc.)
- Store procedure parameters

#### 4.2.10 Update location based data structures

- Overwrite location based data from a given location on-wards (reference location given in the message)
- Insert "Locations" in the data structure, in the order the "Locations" will be passed.

#### 4.2.11 Manage specific location based data:

- movement authority (MA) list of sections, message 37, packet 12 (level 1), message 3, packet 15 (level 2), 16 (repositioning, i.e. extending the current section), message 33 (??), packet 70 (route suitability), message 9 (request to shorten MA), packet 90 (track ahead free leads to MA request) minimum number of elements to be stored: 6
- list of announced BG's linking information: packet 5 minimum number of elements to be stored: 30
- adhesion factor: packet 71; only one element
- the "gradient profile" (in: pkt 21) minimum number of elements to be stored: 50
- Speed profiles: packet 27 (SSP) (the worst case can be determined at reception)
- Packet 13 minimum number of elements to be stored: 50
- Speed restrictions and non-continuous speed profiles: packet 51 (axle load profile), packet 52 (permitted braking distance), packets 65/66 (TSR), packet 88 (level crossing, incl. stop condition to be reset at standstill). minimum number of elements to be stored: TSR: 30, axle load: 30, permitted braking distance: 5 , level crossing: 10.
- Reversing area's: packets 138, 139 minimum number of elements to be stored: 1
- Mode dependent speeds: message 2 and packet 80 minimum number of elements to be stored: 6
- Level transitions: packet 41 minimum number of elements to be stored: (see ss26, 5.10.1.6): 1

- RBC transitions: packet 131
- Radio infill area entry or exit: packet 133
- Loop announcement: packet 134
- DMI information: packets 72,76 (text messages), packet 79 (geographical position information), message 34 (track ahead free request) minimum number of elements to be stored: fixed text: 5, free text: 5, geographical position:
- Track conditions (to be passed to the TIU and displayed at the DMI): packet 39 (traction system), packet 40 (current limitation), packet 68 (diverse track conditions), packet 69 (platform conditions). Pkt 139 minimum number of elements to be stored: 20, + 1 for change power supply + 1 for platform conditions, + 1 for current limitation
- Route suitability: minimum number of elements to be stored: 3
- Big Metal Mass: Technical information (to be used for BG-filtering): packet 67 (ignore BG integrity) minimum number of elements to be stored: 5
- Virtual balise covers: minimum number of elements to be stored: 10
- list of position report locations. In: pkt. 58 minimum number of elements to be stored: 15
- Announced national values. In: pkt 3 minimum number of elements to be stored: 1 - If new national values are announced, then those can lead to more restrictive braking curves. Therefore a speed restriction has to be calculated for the location where the values become valid, based on the targets in advance of this point.

### 4.2.12 Build and update MRSP and list of targets at LRBG

- Overlay speed restrictions (one by one) over the resulting SSP as received from “build location based data”.
- Close the resulting profile with the “end of authority” or “limit of authority” as delivered by “MA-management” resulting in the MRSP at the LRBG. (in on-sight or limited supervision mode, those may not be available)
- Select list of “speed reductions”
- Evaluate (backwards) which targets are relevant, resulting in the list of most restrictive targets at the LRBG.
- Relocate targets (beyond this location) to the “minimum border crossing location”, i.e. the minimum safe location where National values are changed, and add the minimum resulting speed at this location to the list of targets.
- Reasoning: new national values might cause more conservative braking curves which otherwise could lead to an intervention at the border.

### 4.2.13 Profile supervision, i.e. BCM and ceiling speed supervision (active for FS, OS and LS)

- Update MRSP for distance driven, i.e. lower the distance to all speed decreases with the maximum distance driven since last update, lower the distance to all speed increases with the minimum distance driven since last update, reorder the distances in the list if locations to lower and to increase changed order.
- Determine the local maximum speed
- Update the list of targets, i.e. lower the distance to all targets with the maximum distance driven since last update (order will not change) and select the current most restrictive target (always the first in the list)
- braking curve monitoring; calculate the braking curves to the most restrictive target, taking into account gradients

- ceiling speed supervision; monitor against the local maximum speed.

#### 4.2.13.1 Movement supervision

- Roll away protection

#### 4.2.13.2 Area Supervision

In shunting, post trip, reversing and staff responsible an area (plus in some cases ceiling speed) is protected. In unfitted only a speed. The way the area is protected differs per mode therefore a function shall be available for each mode:
- area supervision in shunting (taking into account a list of BG's to be passed)
- area supervision in staff responsible (taking into account a list of BG's to be passed and/or a distance)
- reversing area supervision
- post trip supervision (only reverse movement).

#### 4.2.13.3 Update procedure status (including commanding actions towards driver, radio or RBC)

- SoM:
- EoM
- Enter shunting by driver or track side command override
- Enter "on sight"
- Enter "staff responsible"
- level transitions
- Manage train trip
- Exit shunting
- Passive shunting
- Change train orientation
- Splitting/combining
- Stopping in rear of LX level crossing
- Changing train data (not by the driver)
- Handling track conditions (including indications): not applicable for Amsterdam-Utrecht
- Limited supervision entry: not applicable for Amsterdam-Utrecht
- release brakes (after trip)
- handle track ahead free request

#### 4.2.13.4 Mode/Level management

- Manage all conditions for level changes except the direct transitions (handled in filtering): F41
- Manage all conditions for mode changes (except msg 16 if that leads to a mode change): F42

#### 4.2.13.5 DMI management

- update the MRSP at the LRBG and construct the DMI image
- collect BCM results
- Check displaying of location dependent txt messages
- Calculate geographical position based on stored track-km references
- Display required ack-requests, T.A.F. requests etc.
- Display mode and level information

#### 4.2.13.6 RBC communication

- Manage confirmation requests.
- Report train position
- sent train data for validation
- provide acknowledgements on data reception

#### 4.2.13.7 TIU communication

- Communicate track conditions
- Brake test procedure.

#### 4.2.13.8 JRU and STM management: not applicable for Utrecht-Amsterdam

### 4.2.14 Filter Track informationen

#### 4.2.14.1 Interfaces

**Input from:** Receive MSG Check Consistency and Coordinate System and Train Position
**Output to:** Build Data structure and Location Based/ Build Data Structures Drivers

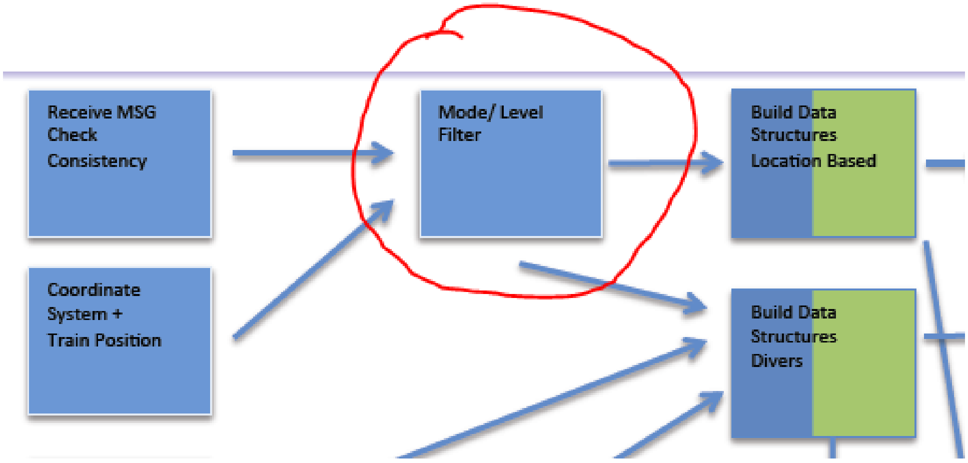


**Figure 9. Filter In and out**

#### 4.2.14.2 SysML Model

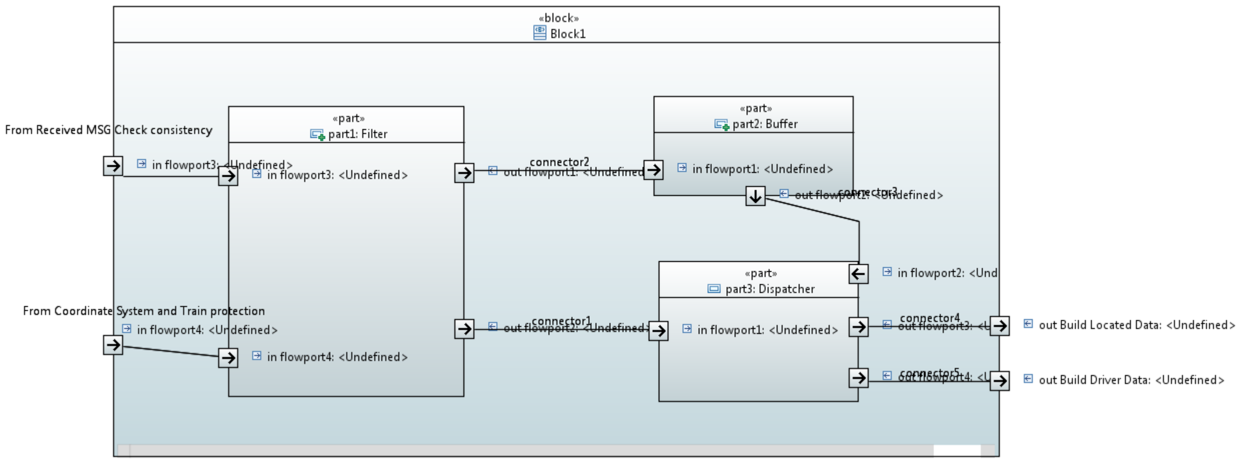


**Figure 10. SysML Filter**

# 5 Design description

## 5.1 Detailed functional description

**Reference to SRS: § 4.8.1, § 4.8.2, § 4.8.3, § 4.8.4**

## 5.2 Documentation of design

§ 4.8.1.6 Messages will be buffered, if...

| | | | | Onboard operating level | | | | |
|---|---|---|---|---|---|---|---|---|
| Number | Package/Variables | Information | From RBC | 0 | NTC | 1 | 2 | 3 |
| | | | | | | | | |
| 1 | Packet 3 | National Values | No | A | A | A | A | A |
| | | | Yes | R [2] | R [2] | R [2] | A | A |
| 2 | Packet 5 | Linking | No | R [1] | R [1] | A | R [1] | R [1] |
| | | | Yes | R [2] | R [2] | R [2] | A [3] | A [3] |
| 3 | V_Main Packet 12 | Signalling Related Speed Restriction | No | R [1] | R [1] | A | R [1] | R [1] |
| | | | Yes | | | | | |
| 4 | Packet 12, 15 | Movement Authority | No | R [1] | R [1] | A [4] | R [1] | R [1] |
| 5 | Packet 80 | + (optional) Mode Profile | | | | | | |
| 6 | Packet 49 | + (optional) List of Balises for SH area | | | | | | |
| | | | Yes | R [2] | R [2] | R [2] | A [3] [4] [5] | A [3] [4] [5] |
| 7 | Packet 16 | Repositioning Information | No | R | R | A | R | R |
| | | | Yes | | | | | |
| 8 | Packet 21 | Gradient Profile | No | R [1] | R [1] | A | R [1] | R [1] |
| | | | Yes | R [2] | R [2] | R [2] | A [3] | A [3] |
| 9 | Packet 27 | International SSP | No | R [1] | R [1] | A | R [1] | R [1] |
| | | | Yes | R [2] | R [2] | R [2] | A [3] | A [3] |
| 10 | Packet 51 | Axle Load speed profile | No | R [1] | R [1] | A | R [1] | R [1] |
| | | | Yes | R [2] | R [2] | R [2] | A [3] | A [3] |
| 11 | Packet 41 | Level Transition Order | No | A | A | A | A | A |
| | | | Yes | A | A | A | A | A |
| 12 | Packet 46 | Conditional Level Transition Order | No | A [11] | A [11] | A [11] | A [11] | A [11] |
| | | | Yes | | | | | |
| 13 | Packet 42 | Session Management | No | A | A | A | A | A |
| | | | Yes | A | A | A | A | A |
| 14 | Packet 45 | Radio Network registration | No | A | A | A | A | A |
| | | | Yes | A | A | A | A | A |
| 15 | Packet 57 | MA Request Parameters | No | | | | | |
| | | | Yes | A | A | A | A | A |
| 16 | Packet 58 | Position Report parameters | No | | | | | |
| | | | Yes | A | A | A | A | A |
| 17 | Package 63 + Message Radio 2 + (optional) Packet 49 | SR Authorisation + (optional) List of Balises in SR mode | No | | | | | |
| | | | Yes | R | R | R | A [3] | A [3] |
| 18 | Packet 137 | Stop if in SR mode | No | R | R | A | A | A |
| | | | Yes | | | | | |
| 19 | D_SR in Packet 13 | SR distance information from loop | No | R | R | A | R | R |
| | | | Yes | | | | | |
| 20 | Packet 65 | Temporary Speed Restriction | No | A | R [1] [2] | A | A [8] | A [8] |
| | | | Yes | R [2] | R [2] | R [2] | A [3] | A [3] |
| 21 | Packet 66 | Temporary Speed Restriction Revocation | No | A | R [1] [2] | A | A | A |
| | | | Yes | R [2] | R [2] | R [2] | A [3] | A [3] |
| 22 | Package 64 | Inhibition of revocable TSRs from balises in L2/3 | No | | | | | |
| | | | Yes | R [2] | R [2] | R [2] | A | A |
| 23 | Packet 141 | Default Gradient for TSR | No | A | R [1] [2] | A | A | A |
| | | | Yes | | | | | |
| 24 | Packet 70 | Route Suitability Data | No | R [1] | R [1] | A | R [1] | R [1] |
| | | | Yes | R [2] | R [2] | R [2] | A [3] | A [3] |
| 25 | Packet 71 | Adhesion Factor | No | R[1] | R[1] | A | R | R |
| | | | Yes | R[2] | R[2] | R[2] | A | A |
| 26 | Packet 72 | Plain Text Information | No | A | R [1] [2] | A | A | A |
| | | | Yes | R [2] | R [2] | R [2] | A [12] | A [12] |
| 27 | Packet 76 | Fixed Text Information | No | A | R [1] [2] | A | A | A |
| | | | Yes | R [2] | R [2] | R [2] | A [12] | A [12] |
| 28 | Packet 79 | Geographical Position | No | A | R [1] [2] | A | A | A |
| | | | Yes | R [2] | R [2] | R [2] | A | A |
| 29 | Packet 131 | RBC Transition Order | No | R | R | R | A | A |
| | | | Yes | R | R | R | A [3] | A [3] |
| 30 | Packet 132 | Danger for SH information | No | A [13] | A [13] | A | A | A |
| | | | Yes | | | | | |
| 31 | Package 135 | Stop Shunting on desk opening | No | A | A | A | A | A |
| | | | Yes | | | | | |
| 32 | Packet 133 | Radio Infill Area information | No | R | R | A | R [1] | R [1] |
| | | | Yes | | | | | |
| 33 | Package 42 | Session Management with neighbouring RIU | No | R | R | A | R | R |
| | | | Yes | | | | | |
| 34 | Packet 134 | EOLM information | No | A | A | A | A | A |
| | | | Yes | | | | | |
| 35 | Messager 45 | Assignment of Co-ordinate system | No | | | | | |
| | | | Yes | A [10] | A [10] | A [10] | A [10] | A [10] |
| 36 | Packet 136 | Infill Location Reference | No | R | R | A | R [1] | R [1] |
| | | | Yes | | | | | |
| 37 | Packet 39, Packet 68 | Track Conditions excluding big metal masses | No | R [1] | R [1] | A | R [1] | R [1] |
| | | | Yes | R [2] | R [2] | R [2] | A [3] | A [3] |
| 38 | Packet 67 | Track condition big metal masses | No | A | A | A | A | A |
| | | | Yes | | | | | |

**Figure 11. Decision**

## 5.3 SCADE Model

# Appendix A: Restrictions on Interfaces to openETCS OBU

The following summarizes restrictions in the scope of implementation of the openETCS OBU. The chosen restrictions are valid for the current scope of the modelling work. They are based on the functions needed to cover the use-case of Utrecht-Amsterdam line.

## A.1 Track to Train Interface

Track to Train Interface: Packets Received and The Coverage in openETCS (Section 7.4.1):

| Packet Number | Packet Name | Relevant in Scope |
|---|---|---|
| 0 | Virtual Balise Cover marker | |
| 2 | System Version order | |
| 3 | National Values | |
| 5 | Linking | |
| 6 | Virtual Balise Cover order | |
| 12 | Level 1 Movement Authority | |
| 13 | Staff Responsible distance information from loop | |
| 15 | Level 2/3 Movement Authority | |
| 16 | Repositioning Information | |
| 21 | Gradient Profile | |
| 27 | International Static Speed Profile | |
| 39 | Track Condition Change of traction system | |
| 40 | Track Condition Change of allowed current consumption | |
| 41 | Level Transition Order | |
| 42 | Session Management | |
| 44 | Data used by applications outside the ERTMS/ETCS system. | |
| 45 | Radio Network registration | |
| 46 | Conditional Level Transition Order | |
| 49 | List of balises for SH Area | |
| 51 | Axle load Speed Profile | |
| 52 | Permitted Braking Distance Information | |
| 57 | Movement Authority Request Parameters | |
| 58 | Position Report Parameters | |

| | | |
|---|---|---|
| 63 | List of Balises in SR Authority | |
| 64 | Inhibition of revocable TSRs from balises in L2/3 | |
| 65 | Temporary Speed Restriction | |
| 66 | Temporary Speed Restriction Revocation | |
| 67 | Track Condition Big Metal Masses | |
| 68 | Track Condition | |
| 69 | Track Condition Station Platforms | |
| 70 | Route Suitability Data | |
| 71 | Adhesion Factor | |
| 72 | Packet for sending plain text messages | |
| 76 | Packet for sending fixed text messages | |
| 79 | Geographical Position Information | |
| 80 | Mode profile | |
| 88 | Level crossing information | |
| 90 | Track Ahead Free up to level 2/3 transition location | |
| 131 | RBC transition order | |
| 132 | Danger for Shunting information | |
| 133 | Radio infill area information | |
| 134 | EOLM Packet | |
| 135 | Stop Shunting on desk opening | |
| 136 | Infill location reference | |
| 137 | Stop if in Staff Responsible | |
| 138 | Reversing area information | |
| 139 | Reversing supervision information | |
| 140 | Train running number from RBC | |
| 141 | Default Gradient for Temporary Speed Restriction | |
| 143 | Session Management with neighbouring Radio Infill Unit | |
| 145 | Inhibition of balise group message consistency reaction | |
| 180 | LSSMA display toggle order | |
| 181 | Generic LS function marker | |
| 254 | Default balise, loop or RIU information | |

## A.2 TIU Interfaces

The following information is based on the structure given by the Alstom API.

### A.2.1 Input to openETCS

| Packet Number | Packet Name | Relevant in Scope |
|---|---|---|
| 0 | Inputs from train devices | |
| 1 | Plain text message | |
| 2 | Fixed text message | |
| 3 | brake models | |
| 4 | Not used | |
| 5 | Not used | |
| 6 | Test and failure detection | |
| 7 | STMs specific behaviour | |
| 8 | Specific from MVB (Specific to Alstom implementation) | |
| 12 | Diagnostic | |
| 13 | Inhibition Level (Specific to Alstom implementation) | |

### A.2.2 Output from openETCS

| Packet Number | Packet Name | Relevant in Scope |
|---|---|---|
| 0 | Commands | |
| 1 | Track conditions | |
| 2 | Odometric data | |
| 3 | Other information | |
| 4 | Train type | |
| 5 | Track condition change of traction power | |
| 6 | Location reference update | |
| 7 | Sporadic commands | |
| 8 | STMs states | |
| 9 | Train information | |
| 10 | Doors control section | |
| 11 | Track description deletion information | |
| 14 | Gradients | |

# Appendix: References

[1] openETCS Product Owner. *WP3 Product Backlog, Selection of First Iteration*. https://github.com/openETCS/SRS-Analysis/labels/backlog%20item.

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[4] openETCS. *openETCS SCADE model*, 2014. https://github.com/openETCS/modeling/tree/master/model/Scade/System.