ETCS INTERFACE WITH THE EXISTING SIGNALLING SYSTEMS

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Abstract
The installation of ETCS systems ensures the interoperability of the trains, but on the other hand shows some issues to interface new equipments with the existing ones. Moreover these interface problems arises both on the physical and on the application layers.
The complete migration from the national signalling system to the ETCS Level 1 and Level 2 systems is achieved only when it is provided a suitable interface.
The necessity to reduce time and costs in the ETCS application projects leads to a sort of standardized solution for the interfaces with a possible customization in order to fulfil the requirements of the existing systems.
The proposal presented in this paper takes into account both the physical and the application layer in order to provide a solution as much general as possible, customizable according to the exigencies of the railways not to have heavy modifications to the already installed systems.
The focus are the ETCS Level 1 and Level 2 applications, providing some examples of the current on-going project.

Keywords
ERTMS/ETCS, interface, interlocking, railways.

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**Acronyms**

ALE - Adaptation Layer Entity  
BTM - Balise Transmission Module  
ERTMS - European Rail Traffic Management System  
ETCS - European Train Control System  
FIS - Functional Interface Specification  
FFFIS - Form Fit Functional Interface Specification  
GSM - Global System for Mobile Communication  
GSM-R - GSM for railway application  
IRI - Interface RBC-Interlocking  
JRU - Juridical Recording Unit  
LEU - Lineside Electronic Unit  
LTM - Loop Transmission Module  
MMI - Man-Machine Interface  
RBC - Radio Block Centre  
SAI - Safe Application Interface  
STM - Specific Transmission Module  
TBL - National Belgian Automatic Train protection system  
TCP/IP - Transmission Control Protocol/Internet Protocol  
TIU - Train Interface Unit  
WAN - Wide Area Network

**1. Foreword**

This document is intended to provide a contribution on the discussion about the possible solutions to upgrade the existing national signalling systems to the ETCS new ones, on the interface point of view.

It has been taken in account the experiences of Ansaldo Segnalamento Ferroviario in the ongoing ETCS projects and it is also proposed a possible new approach for the future ones.

The aim of this discussion it is to find a cost effective solution to be adopted in the development of new ETCS systems onto new lines and old lines already equipped with existing systems to be interfaced with.
2. General Overview of ERTMS/ETCS systems

The European Railway Traffic Management System / European Train Control System (ERTMS/ETCS) is the new signalling standard to be used on the European railways. The ETCS principles can be expressed with a system which controls the safe movement of the train. It is composed of an on-board and a trackside part. The on-board part is a computer connected to the train, and to its braking devices, which dynamically calculates the maximum allowed speed according to the information received trackside. The trackside part sends to the on-board the information coming from the non-ETCS devices (e.g. interlocking, signals…).

The trackside part transmits to the on-board part the Movement Authorities which contain the maximum distance till what the train is permitted to run, and the maximum speed (or zero speed) at the end of this distance. Besides this, the line characteristics are also sent to the train in order to allow the on-board to calculate dynamically the maximum speed.

The Movement Authorities are generated trackside according to the information available in the underlying signalling system, coming from interlocking or other devices present on the field, e.g. the optical signals.

ETCS implementation it is foreseen in three different application levels (Level 1, Level 2, Level 3) according to the different trackside and on-board equipment used and the different means of transmission of the information between on-board and trackside. Another Level 0 is used to indicate the operation of a train equipped with ETCS on-board running on a line not trackside equipped.

The compatibility between the different levels is ensured downwards: i.e. a train equipped with a Level 2 onboard can operate in a Level 2 and in a Level 1 environment.

The different application levels arouse the possibility to adapt the implementation to the characteristics of the lines and to the needs of the railway administrations.

The main innovation of ERTMS/ETCS consists in the possibility to ensure interoperability between different countries/railways administrations increasing the safety and bringing several advantages.

2.1 Integration with the existing Systems

ETCS is a system studied to exist in cooperation with other systems and devices.

For this reason it is necessary that it interfaces with underlying existing signalling system trackside and with the train on-board.

The ERTMS/ETCS standards include a specification of most of the interfaces, as shown in the following Figure 1.

Nevertheless some grey areas still exists which are design issues and are specific for each project. This is because the interface is related to the device and moreover the specificity of the device very often derives from the signalling rules.

In this paper we focus only on the interfaces between ETCS and underlying signalling devices and systems, both for Level 1 and Level 2 applications, disregarding the on-board interfaces and the human-machine interfaces which need another detailed study.
2.2 ETCS Level 1 applications

The Level 1 is a not continuous transmission system from trackside to on-board. The transmission it is realized by Eurobalises devices which transmits the trackside generated Movement Authority to the on-board.

For the Level 1 applications it is always necessary to interface with the underlying signalling system, outside ETCS that is already present on the line.

The Level 1 application needs in the most of cases the presence of optical signals; the information necessary for ETCS to generate the movement authorities can be available in the interlocking or directly in the devices present on the field, e.g. the optical signals.

In both of the aforementioned cases the device which translates these information in a readable format is the Lineside Electronic Unit (LEU), which is connected to the interlocking or the signal and to the Eurobalise.

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* Optical signals are not necessary in case of providing semi-continuous infill, see [4], Part 2, § 2.6.5.1.9
The interface between LEU and Interlocking or signals is not defined in the ETCS standards (see Figure 1 for the interfaces whose specification exists) and it is part of the design activity for a new project.
In the next sections it is better defined which is the current approach followed by Ansaldo.

![Figure 2 – ERTMS/ETCS Application Level 1](image)

**2.3 ETCS Level 2 applications**

The Level 2 is a continuous bi-directional transmission system between trackside to on-board. The transmission it is realized by means of the radio channel provided by the GSM-R network. Also Eurobalises devices are used but only for location purposes. The trackside generated Movement Authority to the on-board are transmitted via the radio channel. For the level 2 applications it is always necessary to interface with the underlying signalling system due to the fact that many functionalities, for instance interlocking and train detection, are outside ETCS.

The information necessary for ETCS to generate the movement authorities can be available in the interlocking or in the devices present on the field, e.g. the optical signals, track circuits, automatic block...

The higher complexity of the Level 2 compared to Level 1 is that this latter application the Movement Authorities are transmitted trackside to on-board, regardless which is the train receiving them, because the transmission is triggered when the train reaches a specific location which is the position of the Eurobalise. In Level 2 application the RBC always knows which is the train to whom it transmits Movement Authorities, so it has to perform other operations to generate the Movement Authority and to check that it is addressed to the “right train”.

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3. Products for ETCS
3.1 RBC

The **RBC** developed by Ansaldo performs the functions required by the ERTMS/ETCS specifications, implementing a set of functionalities ensuring a full compatibility with the standard at the on-board interface level. The RBC essentially performs block functionalities, managing the information received by the on-board (position reports and other messages) and sending to trains all the information (movement authorities, static speed profiles, etc.) they need to move in safety at a full speed.

To provide train headways, the RBC needs that balise groups are correctly configured and installed on the track.

The RBC is composed of different parts, as indicated in the picture, making different functions:
The **Vital Section** is the part of the RBC where there are the Safety functions for: train separation, safe part for the management of the communication with interlocking, next RBC(s) and trains and the control of Functional Keyboard.

The **Functional Keyboard** is the interface where the operator can set speed restrictions or send emergency messages to the trains. The operator sees the RBC operations on a **Graphic Display** and diagnostic data are displayed on the **Diagnostic & Maintenance** interface.
The **Non-Vital Section** manages the functions for operator interface, data logging for diagnostic purposes. All the communication functions are managed by the **Communication Computer**, the communication between the RBC and the on-board system uses the **GSM-R** network and the **Euroradio** protocol. The safety layer of EURORADIO protocol is also used for the communication with interlocking and neighboring RBC(s) for the Italian and Czech applications.

### 3.2 Lineside Electronic Unit

The LEU (Lineside Electronic Unit) provided by Ansaldo is a device connected to the switchable Eurobalises which can change the message sent to the train according to interlocking conditions and signal aspects.

The LEU is composed by different modules:
- the core module (a failsafe device equipped with a watchdog)
- the input field protection module
- the output field adaptation and protection module
- the remote diagnostic module
- the power supply

It is ensured the possibility to interface with serial or parallel input:
- LEU-IS (serial input) can read serial inputs by means of an interface board or a gateway. This can be made in function of the CB-IXL technology.
- LEU-ID (parallel input) normally reads parallel inputs.

According to the national signalling system’s characteristic and taking advance of the ASF product’s modularity, it is possible to customize and optimize the LEU’s composition considering every single railway requirement:

### 3.3 Eurobalise

Eurobalises are non powered devices, standardized by ERTMS/ETCS, to be installed between track lines. When energized by a train passing over them, they send information to the on-board system. The overall set of balise groups constitutes the so called **lineside system**.
4. Current ETCS Projects
4.1 Italian solution
4.1.1 Level 2 application

The Italian High Speed Line application can be taken as a reference for a ERTMS/ETCS level 2 application because it has the full functionality for train detection, interlocking and Automatic Train Protection. The architecture of the system is shown in Figure 9. The main feature of this architecture is that all the lines are new ones, the interlocking are designed for the high speed lines functionalities.

![Figure 9 – Italian high speed line architecture](image)

The implementation of the trackside system of ETCS Level 2 is based on two main classes of components: the Radio Block Centre (RBC) and the Interlocking. The architecture is then composed of:
- A set of distributed sub-systems:
  - Interlocking, main interlocking functionalities
  - Peripheral Post, for the interface to the field (track circuits, switches, etc.)
- A set of central subsystems, the RBC, managing block functionalities.

For reliability and performance reasons, both RBC and interlocking are able to manage only a limited track section: for RBC the length is about 80Km, while for interlocking is limited to 10Km. Therefore, on a typical railway line the number of installed interlocking is about one order of magnitude lower than the number of RBC.

All the interlockings and the RBCs are interconnected in the same Wide Area Network.

The information exchanged between interlocking and RBC, at the application layer, are strictly dependant on the Italian design of the interlocking, related to its specific rules and configuration.
The communication Interlocking/Interlocking, RBC/Interlocking and RBC/RBC is made with a protocol developed by the re-use of UNISIG Safety Layer Euroradio, as indicated below.

The protocol layers are:
- The SAI – Safe Application Interface ensuring additional protections to cover all CENELEC requirements for open and closed communications stated in EN 50159
- The Euroradio Safety Layer, used as it is, indicated in the Euroradio FIS.
- The ALE – Adaptation Layer Entity Is a simple adaptation layer between Euroradio Safety Layer and TCP. It handles redundancy for availability/reliability
- The TCP/IP is the standard one

This solution has been necessary to ensure interoperability among the equipments (RBC and interlocking) provided by different suppliers. For instance on the Torino-Milano line Ansaldo supplied the RBC and the interlockings, while in the Roma-Napoli line the RBC is supplied by Alstom and the interlockings by Ansaldo.

It has been developed as a standard interface between Ansaldo and Alstom and it will be adopted as an European reference.
4.1.2 Level 1 application

This part shows some the achievement of the migration from the national system to the ETCS Level 1 system: in Italy the ETCS Level 1 is being installed over the national system (SCMT).
The two systems can share Eurobalise and LEU trackside and the on-board ETCS has an integrated STM for the SCMT.
The national system information is included in the ETCS Eurobalise telegrams as indicated in the following Figure 12.

![Figure 12 – Integration of ETCS packet](image)

The first application is the Italian Corridor Rotterdam-Genova, where the same technological infrastructure will be shared by ETCS Level 1 and the national system. The ETCS packets will be included inside SCMT existing telegrams, and it is also foreseen the use of radio infill thanks to the already existing GSM-R network.
With this solution it is ensured the traffic of national system equipped trains and ETCS equipped trains, by means of the same technological infrastructure.

4.2 Czech solution

The application of Level 2 in the Czech Republic it is different from the Italian one, mainly because it has to be installed over an existing lines and it has to interface with other signalling equipments already in operation.
The architecture of the system it the one indicated in Figure 13.
The information necessary for the operation of the RBC, provided by the interlocking are centralized via a gateway called “IRI”.
The RBC and the IRI are interconnected in the same Local Area Network.
The information exchanged between interlocking and RBC, at the application layer, are strictly dependant on the Czech design of the interlocking, related to its specific rules and configuration.
The communication RBC/IRI is made with the same protocol used in the Italian application (see § 4.1).
Also in this case the interoperability between different suppliers is guaranteed, in fact the RBC is supplied by Ansaldo while the IRI and the interlocking are supplied by AŽD.
4.3 Belgian solution

The Belgian railways administration began a program to equip the traditional and high speed lines with ETCS Level 1, superimposed to the existing signalling systems. It can be taken as a reference for a ERTMS/ETCS level 1 application because the ETCS equipments interfaces to optical signal and interlocking ensuring the ETCS new functionalities and the already existing ones.

The interfaces are provided with LEU, connected to:

- Computer based interlocking supplied by Alstom (SSI type), connected via serial interface
- Relay based interlocking supplied by Alstom, connected via parallel interface (20 inputs)

The main feature of this project it is that the same technological infrastructure is shared between ETCS: i.e. the Eurobalises laying on the line contain both ETCS information and national system (TBL 1+) information.

5. Migration from the national Systems to the ETCS Application
The European Commission is strongly recommending the rapid deployment of ERTMS/ETCS, and if it is easier to install on complete new lines it could be more difficult on the old ones as described above. In fact in this case it has to be taken in account the old systems that remains in service and the adaptation of the ETCS to an existing system usually old where the modifications are often difficult.

The necessity to reduce time and costs in the ETCS new application projects leads to find also a sort of standardized solution for the interfaces with the existing systems guaranteeing in any case the fulfilment of national requirements taken in charge by these systems.

If it is simpler for the Level 1 applications where it has been shown that the LEU devices already interfaced both in parallel or serially with the existing signalling equipments, it can be more difficult for the Level 2 applications, where the RBC needs specific information coming from the other equipments.

What we propose it is to design an interface composed of two parts: a standard one and a specific one. The customization is obtained at this specific part. This in order to reduce as much as possible the modifications to the ETCS part and to existing part.

The first standardization has to be implemented at the application level. This can be realized finding a minimum set of information necessary to the RBC to calculate the movement authorities. The following information shall be available at the interlocking when present in the interlocking functionalities:

- state of every track circuit (free or occupied) in stations or in lines between stations.*
- state of operator’s commands requiring emergency stops in stations
- state of operator’s commands preventing the sending of trains into a given part of the line between two stations
- aspect of optical signals at exit locations from the Level 2 area
- direction of block system, for exit locations from stations (odd, even, not oriented)
- state of routes:
  - idle
  - set and not blocked
  - blocked and entry not allowed
  - blocked and entry allowed in FS mode
  - blocked and entry allowed in OS mode
  - occupied

The architecture proposed is derived from what adopted in the current projects in which Ansaldo is involved.

The RBC uses a communication network (LAN/WAN) for the connection with other equipments (interlocking, RBC). The protocol used is the Euroradio derived protocol (see § 4.1), since the protection ensured is fully compliant with all the requirements of CENELEC standard.

This solution can be adopted both for computer based and relay based interlocking. The proposal it is to address the interface functionalities to an interlocking gateway which can get information from the interlocking with a parallel interface (to the interlocking side).

This parallel interface can get the available information directly from the relay based interlocking or via a suitable interface layer from the computer based interlocking. This interface gateway will also translate the information, at the application layer, according to the minimum set of information indicated in the list above.

This solution is not technology-dependant and can be easily tailored to all the application ensuring always interoperability between different technologies or suppliers.

* When track circuits are present. In case of line sections with axle counter devices it is possible to consider all the section free or occupied as if it were only one track circuit.
6. Conclusions

The ERTMS/ETCS standard aims at improving safety, reliability, performance and interoperability. These are the main advantages which are common both for the manufacturer and the customer.

The perceived benefits of this proposal are several, all related to have a standard product available with a possible customization.

If this allows the manufacturer to reuse of specification, products and technologies, it reflects to a short implementation time of the project and a reduction of costs.

Moreover it is not necessary to certificate the products, since they needs no modification, but this activity can be focused only to the interfaces.

The proposed protocol stack interface has been officially selected by the EEIG ERTMS Users Group for interface between RBC and between RBC and IXL, and is going to be referenced in the Technical Specifications for Interoperability’s for high speed and conventional railway network.

On the other hand it has to be accepted by the railways a modification to the signalling rules and way to operate. This is necessary to obtain an harmonization among different projects, but can also be a possibility to reformulate rules and procedures according to the present needs.

References

[7] CENELEC EN 50159-2 - Railway applications - Communication, signalling and processing systems; Part 2: Safety related communication in open transmission systems