openETCS: Applying ‘Open Proofs’ to European Train Control
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ERTMS: Global dimensions, global challenges
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Where we are coming from

Europe's railways have developed over the last 150 years within national boundaries, resulting in a variety of different signalling and train control systems, which hamper cross-border traffic (see Figure 1 on page 3). The European Union has decided to improve interoperability for the railway sector. Therefore the European Train Control System (ETCS) as part of the European Rail Traffic Management System (ERTMS) is intended to replace almost all national legacy mainline signalling and train control systems all across Europe. ETCS consists of infrastructure components and on-board units (OBU). A System Requirement Specification (SRS, actual Version: 2.3.0d) has been cooperatively created mainly by six major European railway signalling manufacturers. Those firms have formed an association called UNISIG to manage and coordinate these activities in close cooperation with the EU Commission and the bodies of railway operators. Beginning with the 3rd version of the SRS, this document has been published by the European Railway Agency (ERA), therefore in the 'public domain' and will be mandatory by 2015 for all new infrastructure and train borne signalling and train control equipment.

For the on-board part of the ETCS equipment, the degree of functional complexity to be implemented has turned out to be significantly higher than in conventional signalling and train control systems, thus resulting in substantial cost increases for software development, homologation and maintenance.

Project within the ITEA2/EUREKA framework

In order to overcome these problems, a project has been proposed to the ITEA2 programme committee and was finally approved at the end of 2011. ITEA2 stands for 'Information Technology for European Advancement' and is a part of the EUREKA cluster programme; a Europe-wide research and development intergovernmental network initiative. ITEA 2 is devoted to pan-European programme for advanced precompetitive research and development in software. Each project is supported financially by the country members of the EUREKA framework.

The purpose of the project is to develop an integrated modelling, development, validation and testing framework for leveraging the cost-efficient and reliable implementation of ETCS. The framework will provide a holistic tool chain across the whole development process of ETCS software. The tool chain will support the formal specification and verification of the ETCS system requirements, the automatic and ETCS compliant code generation and validation, and the model-based test case generation and execution. It will utilise ‘Open Standards’ on all levels, including hardware and software specification, interface definition, design tools, verification and validation procedures and, last but not least, embedded control software. By applying those technologies and related
business concepts, a significant cost cut for the final on-board product is expected down to or even below conventional high performance cab signalling systems (e.g. LZB Linien-Zug- Beeinflussung, as used in Germany, Austria and Spain). The open source concept provides for a neutral and formal method based ‘correct’ functioning reference device that will help to overcome existing interoperability problems, supporting manufacturers, infrastructure managers and railway undertakings alike, avoiding exhaustive field tests, transferring verification and validation activities from the track site into laboratories, saving scarce resources and finally accelerating the migration process and therefore supporting the European ERTMS deployment plan.

State-of-the-art technology and potential ‘Road Blocks’

The EVC (European Vital Computer) is the heart of the ERTMS on-board system. This safety computer implements the functions of the SRS subset 026 of UNISIG (for SRS versions beginning with baseline 3, published by ERA) in order to guarantee the safety of the train movements.

The EVC is also the carrier of interoperability in the ETCS vision:
- An on-board system has to be able to execute any SRS-function
- An on-board system has to be able to execute different versions of the SRS to guarantee the upward compatibility (see subset 26 – §6).

Due to these characteristics, most of the UNISIG members have chosen to develop the EVC software as generic software intended to be reused in different application projects with a specific configuration. This model ensures that a continuous return of experience is injected back in the software development, ensuring a convergence to maturity. However, up to now there was little cooperation at the level of software development between these manufacturers (see Figure 2 on page 4).

The development of the EVC software is performed using the methods described for software development in CENELEC EN 50128 for SIL4 software. The level of reliability required by the standard strongly increases the number of activity to be performed to release a software version.

The software development is facing the following difficulties or criticisms:
1. The SRS specification is written in natural English language relying on free drawings that can be interpreted in slightly different manners by the designers in charge of making the software
2. The SRS specification has to be refined, because it is written as a system specification without making a clear allocation between trackside and train borne functions
3. Due to its start in the late 1990s, the software has been based on traditional software development methodologies (traceability between specification layers, independent code review, unitary tests etc…) that requires extensive work in case of software modifications
4. The SRS specification has frequently changed and evolved through the years, making the non-regression work in between the successive versions consequent and costly
5. The development work in parallel by several
manufacturers of the EVC software code makes the necessary investment huge and final products very costly.

Despite the fact that several major European suppliers with substantial knowledge in signalling technology have worked on the aforementioned common System Requirement Specification for more than a decade, and considering above mentioned difficulties, the main goal of interoperability has not yet been accomplished. Up to now, not a single ETCS on-board unit has been approved to operate on all existing European ETCS lines. Therefore, the on-going development of ETCS has to be considered as ‘work in progress’ resulting in many software upgrades to be expected in the near and distant future.

A lack of standardisation on various levels, different national homologation procedures and a diversity of operational rules combined with interfacing to several legacy systems during a lengthy transitional period has to be considered as major cost drivers. Almost all products on the market are based on different proprietary software designs, which results in a life-long dependency from the original manufacturers causing high lifecycle costs for vehicle owners.

On the other hand, several programmes where several competing manufacturers do not only agree on common functional specification documents, but common design principles and even specific common interfaces and common HW and SW designs (AUTOSAR®) or software development platforms (TOPCASED®) in order to share cost and improve overall product quality.

Pre-competitive cooperation by Open Source principles

The key element for improving that situation seems to be a greater degree of standardisation for hardware, software, documentation, methods and tools in combination with formal methodology and modelling technique, applying open source license schemes to promote and encourage EU wide cooperation (see Figure 3 on page 5).

The proposed open source approach is utilising concepts from the automotive and aviation industry, not only covering the embedded control software of the ETCS on-board unit itself, but including all tools and documents in order to make the entire product
life cycle as transparent as possible and make it comprehensible for third parties. Making the proof of safety open to the entire professional world has been called ‘Open Proof’ and is new to the railway sector.

The European avionics sector (Aerospace Valley) has already developed its own open source tools chain and has successfully created an eco-system, which maintains a Software Development tools Kit (SDK), called TOPCASED, based on the widely used open source Eclipse software platform.

TOPCASED was specifically designed to suit the needs for functional specification, software development and verification for highly safety critical vital flight control applications. Since requirements are quite similar for railway and aviation safety equipment, such tool chains would form a good basis for openETCS. These tools need however to be adapted to mandatory technical processes and norms (CENELEC), in particular EN 50128, for safety critical software in the railway domain.

Such an holistic approach will therefore cover not only the implementation of the (core) functionalities of the ETCS on-board unit itself, but also semiformal and formal models, the results of the verification and validation tasks as well as the test-cases, the test and simulation results, the tools that have been applied during the various steps and a structured argumentation that the whole process has been carried out in a way that the result is accepted to be safe. This approach is called ‘Open Proofs’ (see Figure 4 on page 6).

In the automotive and aviation industry, there exists, to a certain degree, similar approaches. To not reinvent the wheel, those approaches and already existing tool-chains (e.g. TOPCASED) will be examined, evaluated and, if so adopted to the specific needs of the railway sector (CENELEC norms, EN 50128).

Thus, the technical innovation lies in the development and provision of an integrated system consisting of interrelated models, proofs, tools and the corresponding documentation for application experiences of the suppliers and the theoretical knowledge and approaches from the research partners.

Expected results
The results of a successful openETCS project will lead to the following potential products and services:

- openETCS platform: Open source platform for validation and verification of ETCS requirements. Then openETCS platform will be based on a consistent integrated software tools chain and open proofs concept for formal modelling, validation, and verification of ETCS requirements. The tools chain will include the necessary software tools.
- Open Proofs Concept: Open Source Software (OSS) methodology will be extended to an ‘Open Proofs’ concept. With ‘Open Proofs’ the development process of complex safety-related ETCS systems will be made more transparent and the entrance level to formal methodologies will be reduced.
- Formalised ETCS requirements: Formalised ETCS requirements that are

Most of the UNISIG members have chosen to develop the EVC software as generic software intended to be reused in different application projects with a specific configuration.
Long-term maintenance service:

● openETCS – kernel and abstraction layer: Provision of new services and offerings for the development of V&V of safety critical embedded controlled systems in the railway sector.

Future OBU development:

The open source platform for validation and verification of ETCS requirements leads to a lean and sustainable development of on-board units (OBUs) possibly based on COTS hardware and software components, which is not the case in today’s ETCS systems.

openETCS – kernel and abstraction layer: The openETCS platform will be supported by an openETCS kernel and an openETCS abstraction layer necessary to support future ETCS hardware platform and virtual systems during long lifecycle.

Long-term maintenance service: Because ETCS systems have very long life-cycle (2-4 decades) new maintenance services will be established. This will result in updated and modern ETCS and will improve safety significantly.

Hence, existing and operating OBUs can be easily verified against these new requirements by the operating company and, if necessary, be updated by the developing company... 

Services around openETCS platform:

The major goal of unified European train control, signalling, and train protection system, ETCS, has led to highly complex functionality for the on-board units. A lack of standardisation on various levels, combined with interfacing to several legacy systems during a lengthy transitional period has to be considered as a major cost driver. Therefore, even compared with some of the more sophisticated legacy ATP and ATC systems in Europe, ETCS has turned out to be far more expensive without providing much, if any, additional performance or safety advantages. Therefore an open source approach has been suggested, not only covering the embedded control software of the ETCS on-board unit itself, but including all tools and documents in order to make the whole product life cycle as transparent as possible optimising economy, reliability, safety and security alike. This concept is called ‘Open Proof’ – a new approach for the railway signalling sector.

Reference

1. UNISIG stands for ‘Union of Signalling Industry’ and is an industrial association with all major European signalling manufacturers being members, who provide ERTMS related products and services.

2. ITEA 2 Project Outline Full Project Proposal Annex, openETCS: Open Proofs Methodology for the European Train Control System; Project No.: ITEA 2 11025, 30.09.2011, Document: 11025_openETCS_FPP_Annex ITEA_20110910_v2.2


BIographies

Dr. Klaus-Rüdiger Hase has worked for Deutsche Bahn since 2002, and is currently at DB Netz AG in charge of the ‘European Train Control System’ on-board programme. Until 2007 he was managing DB’s regional EMU/DMU engineering group. His earlier work included at AEG Transportation in Berlin and Pittsburgh, PA, USA) before he became Head of R&D for on-board electronics at Knorr-Bremse, Munich. In 2008 he launched DB’s international openETCS initiative and is heading the European openETCS project within the ITEA2 programme (EUREKA).
Revolutionising railway communications with LTE

As Long Term Evolution (LTE) is rolled out on commercial mobile networks across the world, 4G wireless network is also being adapted to railway communications, allowing operators to improve the efficiency of their critical operational communications and enhance passenger experience by offering new and innovative services.

Access to ultra-high-speed broadband plus high-definition and 3D TV is the future of mobile telecommunications. Within just a few years, anyone will be able to utilise these bandwidth-hungry services from their smartphone, game console, tablet or laptop by accessing a fourth-generation (4G) network.

Long Term Evolution (LTE) is gaining traction as the preferred standard for 4G with more than 50 commercial networks launched between 2009 and the first quarter of 2012, and 128 expected by the end of 2012.

Rail users will also expect access to these services. Indeed, LTE has the potential to transform the passenger experience by enabling operators to offer innovative services such as individual journey plans, tailored marketing messages, and communications during service disruptions. However, the benefits offered by LTE are not limited to passengers. By hosting all communications on a single platform, an LTE-based network can revolutionise an operator’s critical communications while optimising traffic and reducing costs.

Railways must therefore consider investments in a high bandwidth IP backbone as the first step towards a multi-service communications network that will support LTE. This might seem a daunting prospect, but as the European Commission noted in its 2009 document A Sustainable Future for Transport, “upgrading existing infrastructure – also through intelligent transport systems – is in many ways the cheapest way to enhance the overall performance of the transport system.”

Optimising operations and saving costs with LTE

Advances in telemetry and machine-to-machine (M2M) interfaces that provide real-time monitoring are already promoting a shift towards predictive rather than preventative maintenance. Real-time traffic management and driver advisory systems will aid efficiency. And when the time comes to upgrade to LTE, the high bandwidth on offer will allow communications and safety applications such as signalling, CCTV, VoIP, and entertainment streams to coexist on a single platform without compromising safety.

Alcatel-Lucent is currently testing LTE with existing signalling systems with a view towards superseding GSM-R, Tetra and Wi-Fi communication networks. Some of these systems were developed for the pre-IP era and are limited to ground-to-train voice communication and early CBTC with restricted data exchange or, in the case of the Wi-Fi networks, are unsuitable for moving objects. By contrast, LTE is designed to deliver truly mobile multiple broadband IP-based services, and in conjunction with its sophisticated Quality of Service (QoS) mechanism, is capable of prioritising various application traffic streams without compromising reliability.

With such substantial changes on the horizon, railways must be ready to capitalise. Choosing a supplier with suitable experience is therefore crucial.

Alcatel-Lucent is already working with Adif and Metro Madrid in Spain as part of the TECRAIL project to identify the most effective transition of LTE to mainline and urban railway communication networks. These emphasise an end-to-end solution and interoperability with legacy networks, meaning that any operator upgrading to an intelligent transport system will receive a comprehensive package that will
ERTM: Global dimensions, global challenges

‘European Rail Traffic Management System (ERTMS): Global dimensions’ was the theme of the latest UIC Global ERTMS Conference, which took place in Stockholm on 24-26 April 2012 and clearly highlighted a major shift in the history of this signalling system.

From a technology built to ensure interoperability on European railways, ERTMS has now moved to a global signalling standard. A system designed initially for freight and high-speed traffic, it is now showing its capability to be used in a suburban environment. Equally, it also faces a number of challenges, related for instance to its deployment in Europe – which is sometimes slower than originally expected – contrasting with the original European aim but showing its significant global success.

ERTMS deployment – where are we?

The recently published UNIFE ERTMS statistics offer an interesting perspective with respect to both the impressive level of investments worldwide and on the suitability of ERTMS for various rail operations.

Firstly, the number of railway lines already equipped or contracted to be equipped with ERTMS has substantially grown in recent years, reaching a total figure of 62,000km (against 37,000km in September 2010). Equally, more than 7,500 vehicles are already running or contracted to be equipped with ERTMS.

In terms of geographical coverage, Europe still accounts for the majority of the investments, but significant contracts have been signed in non-European countries in recent times. Whilst ERTMS has been traditionally successful in Asia, China, Taiwan and South Korea in particular, new markets have emerged in the past two years in other regions such as Africa and the Middle East (where the Gulf countries are building significant railway networks which will be interconnected using ERTMS), Latin America (Brazil) and Oceania (Australia, New Zealand). There are in total 38 nations around the world investing into ERTMS – quite a considerable figure for a system which is still considered as ‘young’ in railway signalling terms.

ERTMS, a global standard for signalling worldwide

Focusing on the investments outside Europe, ERTMS also shows its suitability to a variety of applications, including:

- High-Speed Rail: ERTMS is already in service on Chinese and Turkish high-speed lines; major contracts have been awarded in other regions of the world, such as the Saudi Arabia (Mecca-Medina high-speed line), whilst the US is considering its use for the country’s future high-speed programme
- Freight: major investments have been made in the Gulf & Middle East (e.g. Saudi Arabia, United Arab Emirates), India or Indonesia, to use ERTMS in freight applications
- Suburban applications: this latter trend was perhaps unforeseen, but ERTMS is increasingly used in a suburban context, with contracts signed in Brazil (Rio suburban network), Mexico DF, Australia (Sydney suburban) and New Zealand (Auckland).

These successes are a fantastic showcase for the European rail supply industry. Being offered by all major European rail suppliers, ERTMS has become a de facto worldwide signalling standard. Whilst most of this success can be explained by the advantages it brings in terms of supplier-to-supplier compatibility, flexibility and performance, cross-border interoperability is also becoming an important factor, typically in the Gulf countries. This success also shows that the ‘business case’ of ERTMS – which is sometimes pointed out by some European railways – is right in many nations around the world which do not have any legal obligation to invest into this system. In many respects, this demonstrates a paradoxical evolution of a standard defined in Europe but which is enthusiastically adopted abroad.
The ERTMS specifications and worldwide needs for signalling

Such drastic evolution towards a global standard also raises the issue of the ERTMS specifications and the way they are written today. For obvious historical and political reasons, Europe is the ‘home’ of the ERTMS specifications, which are under the responsibility of the European Railway Agency (acting as system authority) with the support of the EU rail sector organisations. Is a situation whereby a standard used primarily outside European borders being defined by European stakeholders sustainable in the long run?

Several remarks can be made on the challenges arising from the ‘globalisation’ of ERTMS.

Firstly, the use of GSM-R is questioned by many nations around the world. Several countries wishing to use ERTMS face issues of GSM-R availability, whilst others wish to use different or more modern telecommunication means (e.g. TETRA, IP-based like GPRS). In the medium-term, the creation of ‘bearer-independent’ devices, instead of railway-specific telecommunication means, seems unavoidable.

Secondly, ERTMS is increasingly used in a Suburban context – as shown by the investments made in the Rio de Janeiro, Auckland, Sydney or Mexico DF suburban networks. Such developments called for the implementation of new functions and interfaces – for instance Automatic Train Operation (ATO) or connection with ‘urban’ signalling environment to cope with demands for short headways and higher throughputs.

Thirdly, ERTMS has – for the reasons explained above – been designed primarily for the needs of the European network, marked by the coexistence of high-speed lines, and a high density freight and conventional passenger network. Worldwide, countries’ needs may differ in this respect. Indeed, a large number of countries around the globe (Russia, Australia, etc.), due to their specific geographical situation, may wish to implement ERTMS on long, low-density lines. From this point-of-view, the use of satellite navigation, as an alternative to a balise system which may be subject to theft or high temperature, may seem appropriate.

Whilst some of these evolutions are already ongoing in Europe (use of GPRS and ATO in particular), these ‘non-European’ needs could well play an important role in the evolution of the standard in the coming years.

The European dimension: an uneven situation

Within Europe, ERTMS investments remain largely uneven. Some countries like Switzerland, Belgium or Denmark have launched major investments in 2011 and 2012, with contracts signed to equip their entire railway networks. Conversely, some other countries right in the middle of Europe are still lagging behind, despite the European ERTMS Deployment Plan, which makes investments mandatory on a number of key freight Corridors by 2015 and 2020.

ERTMS deployment in Europe: a political debate, besides technical issues

One can wonder how long a situation where some of the largest networks in Europe continue to postpone investments whilst the other massively equip their networks will last. Indeed, the ‘traditional’ arguments against the deployment of ERTMS have been shrinking in previous years:

- The complaints about the ‘teething problems’ and ‘lack of supplier-to-supplier compatibility’ now seem partly, if not totally irrelevant. ERTMS is now in operation in a considerable number of countries; more importantly, customers of ERTMS are very happy with the system; we touch here a very typical ERTMS paradox, whereby customers are actually happy with the system, whilst those complaining about it are investing little in it
- The issue of the ‘stability of the specifications’ is also behind us. In this respect, the adoption of the Baseline 3 of the specifications in April 2012, after considerable work achieved by ERA and the sector, marked an important milestone, completing the work of the 2.3.0d version adopted in 2008
- The complaints on the ‘costs’ of the system are also losing ground. Firstly, the global success of ERTMS tends to demonstrate that it is highly price competitive. Secondly,
Empirical analysis show that prices are strongly decreasing to a very large extent. Thirdly, the suppliers have taken a number of initiatives to standardise some interfaces (Train Interface Unit, investigations on the DMI-EVC interface) that will further reduce costs and ease the acceptance of the system. Lastly, UNIFE has also conducted some analysis on the cost breakdown of ERTMS, showing the areas that should be investigated for further cost reductions (typically, reducing the number of legacy systems and especially reducing authorisation costs). These issues are currently considered by the EU Institution (please see below, ERTMS Memorandum of Understanding).

The challenge for ERTMS deployment in Europe therefore appears as a ‘political’ rather than a ‘technical’ concern. Are the Member States ready to invest in a system that brings sometimes more ‘European’ added-value than purely a National one? Are stakeholders ready to ‘forget their darlings’ and adopt a new system for the European common good? Finally, is the European railway community mature enough for interoperability and full competition?

Opening new perspectives
The Memorandum of Understanding signed in April 2012 in Copenhagen by the European Commission (Vice President Kallas) and the railway associations (UNIFE, CER, UIC, UNIFE, EIM, GSM-R Industry Group and ERFA) further reinforces the cooperation amongst stakeholders and opens new opportunities for ERTMS.

In particular, it recognises the need to migrate the existing installations, many of which were put into operation in the 2000s, to an interoperable Baseline (2.3.0d and/or Baseline 3). Such coordinated migration will ensure that ERTMS-equipped trains may run on any existing ERTMS lines. The Memorandum also underlines the need for stable specifications, which has been achieved with the Baseline 3 documents published in April, whilst ensuring some technical cooperation on matters of interests (typically testing).

Importantly, the text also recognises the costs of ‘non-Europe’ when it comes to ERTMS: a coordinated migration to ERTMS of existing lines, as opposed to fragmented investments, would strongly improve the business for rail operators. So would the gradual de-committing of legacy systems. Equally, a simplified authorisation scheme for railway equipment would greatly reduce the costs of ERTMS – today authorisation accounts for a major share of the costs of the equipment!

In many respects, decision-makers, operators, infrastructure managers and suppliers have a clear roadmap ahead, as underlined by the Memorandum of Understanding. It will be a joint responsibility of the sector to successfully deploy ERTMS in Europe and make the system as successful in Europe as it is on the worldwide stage.
The 8th annual Rail Network Solutions conference will once again be hosted by MÁV Railways, attracting delegates from government, rail infrastructure managers, train operating companies, consultants and suppliers.

With HUF 753 billion available for the implementation of railway projects, Rail Network Solutions 2012 will provide crucial information on the tender and roll-out plans for Hungarian rail nationwide. MÁV will host a technical site visit on 17 October with a full day conference of keynote presentations and detailed panel discussions on Thursday 18 October.

www.railnetworksolutions.com