Innovative platform for interoperability of multimedia applications on board trains paves the way for better services and new market perspectives

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Abstract

Sustainable development strategies currently deployed in all major countries in the world plan to shift relevant shares of traffic from other transport modes to rail, so as to take advantage of its lower environmental footprint.

To achieve this, railways need to meet increasing customer expectations in terms of performance (especially punctuality and integration with other transport modes), security and comfort. Innovation will play an essential role in achieving such objectives at reasonable cost. Improvement can be achieved in four different areas:

1) Security orientated services (like on-board surveillance and access control)

2) Passenger orientated services (like distribution of information and entertainment)

3) Driver and Crew orientated services (like energy monitoring and electronic ticketing)

4) Operator and Maintainer orientated services (like quality monitoring and diagnostics)

Today, such subsystems are often poorly or not at all integrated, follow proprietary specifications and are difficult to maintain, upgrade and replace. All this means higher than needed life-cycle costs and often unsatisfactory performance levels.

Using a modular, open and standard platform as a common basis for building up such subsystems and related services can greatly contribute to improve the situation:

- Design and development can be quicker and cheaper using standard components;
- Installation and configuration can be easier;
- System integration can be almost or totally automatic;
- Individual components can be replaced with the most convenient alternate products.

This paper presents the results of wide investigation into requirements and use cases and possible alternate solutions. Main result of the research is the proposed platform, which is based on a SOA (Service Oriented Architecture) approach and allows to build up multimedia applications by means of reusable services, communicating each other through XML-based messages. In order to take into consideration the railway environment, tailored solutions have been adopted, like DPWS (Device Profile for Web Services) which is a light version of SOA specially targeting embedded devices, and ASN.1 coding (to shrink XML message size by more than 90%).

Future products compliant with the envisaged standard solution will offer benefits like easier commissioning, simpler system maintenance, lower life-cycle costs.

An important benefit will be to lower entry barriers to market, allowing new companies (especially SMEs) to start new products and easily integrate them within final systems.

1. State of the art in railway multimedia applications

European policy and strategies for a sustainable and intelligent growth include railways as a key element, as the only solution to meet their objectives is to shift part of the growing transportation demand from other modes to the railway system [1], [2], [3].

For this to happen, railway services need to become more attractive in terms of performance, quality and cost, both to passengers and goods, so matching customer expectations for a seamless and effective transport service. Information and Communication Technologies can play an important role creating improved or new multimedia and telematic applications.

Four different areas have been identified, where innovative services are possible and needed:

1) Security orientated services (like on-board surveillance and access control)

2) Passenger orientated services (like distribution of information and entertainment)

3) Driver and Crew orientated services (like energy monitoring and electronic ticketing)

4) Operator and Maintainer orientated services (like quality monitoring and diagnostics)

Today, such subsystems are often poorly or not at all integrated, follow proprietary specifications and are difficult to maintain, upgrade and replace. All this means higher than needed life-cycle costs and often unsatisfactory performance levels.

Such situation is no more acceptable and stakeholders (final users but also railway operators) clearly expressed [4] their requirements for new products based on a modular, open and standard platform, which will take advantage of existing technologies, often already deployed in other sectors.

2. Role of SOA

The proposed platform is based on a Service Oriented Architecture, where services, accompanied by their service descriptions, communicate by means of messages. So far, this architecture appears similar to distributed architectures which support messaging and separation of interface from processing logic. What makes SOA different is how its three core components (services, descriptions and messages) are designed. This is where service orientation as a set of design principles comes in. Let us mention the service orientation principles and their key aspects as given in [5]:

- Loose coupling: services maintain a relationship that minimizes their mutual dependencies.
- Service contract: services adhere to a communications agreement, as defined by one or more service descriptions and related documents.
- Autonomy: services have control on the logic they encapsulate.
- Abstraction: beyond what is described in the service contract, services hide logic from the outside world.
- Reusability: logic is divided into services with the purpose of promoting reuse, i.e. to be used in different contexts.
- Composability: collections of services that can be coordinated and assembled to form composite services.
- Statelessness: services minimize retaining information specific to an activity.
- Discoverability: services are designed to be self-descriptive so that they can be found and assessed via available discovery mechanisms.

As a SOA implementation solution, Web services are the most common technology at present. The main reason for this is that solutions based on Web services adhere naturally to many of the service-orientation principles. In response to current industry trends and developments, the basic set of standards which formed the original Web services technology platform has been substantially extended by new specifications. This resulted in extended variation and additional common characteristics of this up-to-date SOA. These characteristics are embodied in the following definition taking into account the technology used: “SOA represents an open (based on open standards), extensible, composable architecture that promotes service orientation and is comprised of autonomous, QoS-capable (reliability, security), vendor diverse, interoperable, discoverable, and potentially reusable services, implemented as Web services" [6].

Even though enterprise systems remain the main application area of SOA, the ever-increasing computational power and connectivity of embedded devices has made SOA applicable also to the industrial sector. The introduction of SOA at equipment level reduces the technological barrier to the enterprise level and simplifies system integration. In the railway sector we can expect a number of integrated applications, owned for instance by a railway operator, using services located both on-board trains and on the ground.

At device level, SOA comes in a flavour labelled "Device centric SOA" [7] which considers autonomous intelligent devices as its prime entities, in contrast to purely functional units as in the case of "classical" SOA. This approach, which has been also adopted for solutions on board trains, is supported by DPWS (Device Profile for Web Services) [8] the standard which tailors the selected set of Web services standards and specifications to use them on resource-constrained devices. In addition to base standards as SOAP (messaging), HTTP (transport) and WSDL (service description in a machine-processable format) this set includes a number of WS-* extension standards and specifications. For example: WS-Addressing, WS-Discovery, WS-Policy, WS-Security, WS-Eventing. The DPWS has been set as a basis for experiments which shall result in the decision whether DPWS can be used as it is or a railway specific profile will be needed. Currently, the experiments are underway.

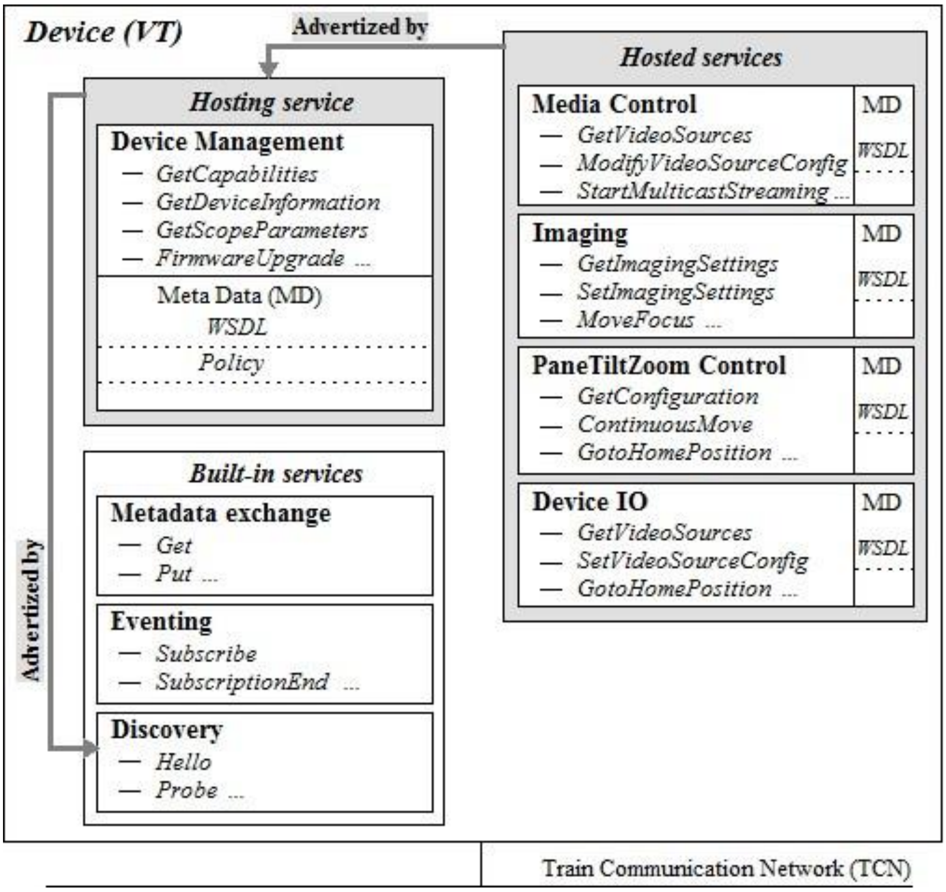

Figure 1 - Web services in a video camera device (an example)

The DPWS defines two types of services running on devices:

- hosting services, which are directly associated with a device, participate in the device discovery process and act primary as a resource containing device-wide data and basic information about hosted services,

- hosted services, which are mostly functional and rely on their hosting service for discovery.

In addition, DPWS specifies the following services which can be considered as built-in services:

- Discovery services, used by a device to advertise itself and to discover other devices (without the use of a global service registry), provide a plug-and-play mechanism.
- Metadata exchange services retrieve metadata related to a device and hosted services.
- Eventing services enable devices to subscribe to events on another device.

Figure 1 gives an example of a video transmitter DPWS device (e.g. video camera) which is a component of a video surveillance system. Device's services and some of their operations are shown. The operations represent mostly control and configuration functions. Services, operations and messages assigned to operations are defined in WSDL documents, which are stored, or references to them are stored, in the device. Type, name, location or some other device's properties can be used by the discovery services.

While building the platform, we cannot overlook the question about how to increase the intelligence of the services. Knowledge in machine-readable format is a key to it. Semantic technologies, which cover a wide range of techniques based on knowledge representation, have to be employed [12]. They aim to make data from different domains become available and useful through formal information models, which capture domain knowledge, e.g. ontologies, through automated reasoning and standardized query languages. Semantic technologies that were embodied in W3C standards are of prime interest for industry. Web Ontology Language (OWL) [13, 14] has been designed for the description of ontologies and SPARQL is a standard query language for retrieval of the knowledge which they capture. The following use cases can be considered for semantic technologies in the area of multimedia and telematic applications in a railway domain:

- Information integration and decision support: semantic information integration provides a more scalable way to integrate information from heterogeneous sources. It is based on shared ontology or mapping between ontologies.
- Automatic Web service discovery: use of ontologies to implement a semantically enhanced mechanism for service discovery, in contrast to the usage of keywords for this purpose.
- Automatic Web service invocation: invocation of a Web service by a client, when only a description of that service is given, as opposed to the case in which the client has been pre-programmed to be able to call that particular service.

As an example of complex application, where intelligent services, located on board and on the ground, cooperate in the realization of various scenarios, we can consider Multimedia-on-Demand. The list of its main services indicates the functionalities of this application.

- Personal Interface Service: interacts directly with the passenger, interprets requests and presents information in a user-friendly manner.
- User Profile Service: maintains passengers' profiles containing information as the type of ticket, personal preferences given, which regulate the offered content.
- Program Guide Service: maintains information about multimedia contents and shapes the offer according to a given user profile.
- Content Update Service: is responsible for getting multimedia contents from the ground.
- Multimedia Storage Service: handles on-board multimedia storage devices.
- Video-on-Demand Control Service: controls streaming service on multimedia sources.
- Central Control Service: controls the activities of other services to accomplish a given goal.
- Content Provider Service: on-ground service providing multimedia contents for trains. Supposedly this service is also used within an application for contents preparation which is run by the content provider organization.

Information about multimedia contents and that related to passengers can be stored in a repository based on an Ontology, which is shared by services. [15]

3. Secure and efficient coding

The previous chapter introduced the framework that should be used for applications to interact on board trains. Further constraints of the railway environment must also be taken into account when designing the operational platform.

The onboard communication network is subjected to harsh EMI and mechanical environmental conditions. For this reason proven and resilient communication technology is normally used. It means that 100 Mbps copper wire usage is widespread for Ethernet communications.

In parallel, the advance in connected services implies an increase in the volume of data exchanged. Furthermore, the system must provide external access. Typical examples are the real-time Passenger Information System, or Maintenance applications.

Consequently, for the operational platform, the following problems must be addressed:

- security
- efficiency

Security of messages

DPWS is able to provide security mechanisms at user level. They can fulfill part of the requirements defined in the IEC 62280 standard [16]. These DPWS mechanisms complement security mechanisms available at transport level or network level.

WS-Security is a standard feature of DPWS (figure 2). This layer provides:

- security tokens
- signature elements
- encryption elements

WS-Secure Conversation can also be used in coordination with WS-Security to establish a secure connection and diminish the processor load necessary for encryption (using symmetric keys).

These basic building blocks can be used to

- Ascertain the identity of source and destination
- check the integrity of messages
- assure the confidentiality of messages

Security provided by DPWS is implemented by only adding an intermediate layer and does not change the architecture of the application. However, to assure interoperability, some standardization work would be necessary for defining in detail how each element will be used.

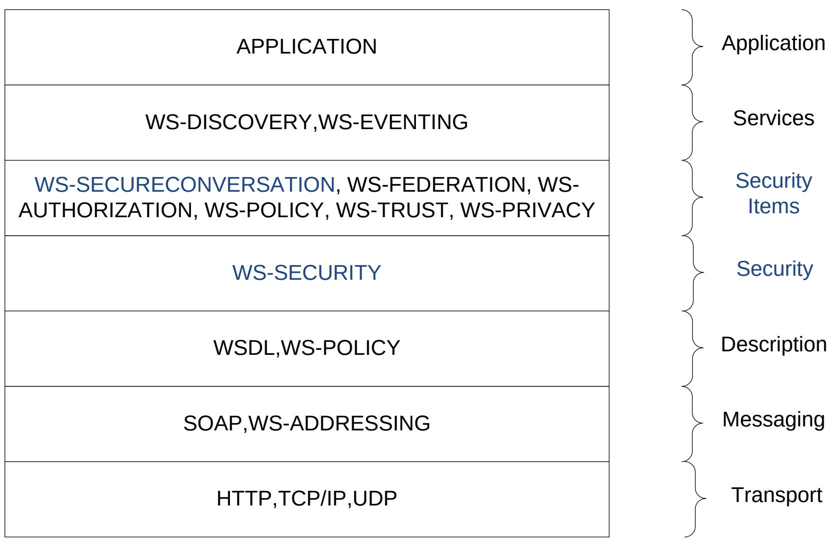

Figure 2 – DPWS-based communication stack with security

Efficiency of messages

DPWS is the preferred method selected for implementing SOA services on board trains. It is based on XML which is widely used in the Internet domain. The advantage of using XML is that many peripherals can be adapted with slight modifications. However, XML as a transfer protocol is inefficient since it relies on ASCII encoding. On the train network, because of the limited bandwidth, compression should be considered.

Several methods can be devised to compress data. ASN.1 (ISO/IEC 8824) [17] encoding methods seem to be appropriate. ASN.1 encoding protocol is the method used in wireless telecom communications. The first step would be to transform the XML message to/from an ASN.1 message. This part has been specified in the standard ISO/IEC 8825 [18, 19, 20]. By doing the transformation at the right place, such transformation will be transparent to the SOA designer while providing efficient communication exchanges.

A preliminary study comparing different compression methods has shown that ASN.1 using Packed Encoding Rules offers the best compression factor. We can expect a reduction in data volume in the magnitude order of more than 90% for train related communications.

4. First experiments

Following extensive investigation, we decided to experiment with DPWS [8], the best candidate, in our opinion, for Web Services on trains.

In detail, DPWS 1.1, the release we chose to work with, encompasses the following standards:

1. Soap 1.2
2. WS-Addressing
3. WS-Discovery
4. WSDL 1.1
5. WS-Eventing
6. WS-Policy
7. WS-PolicyAttachment
8. WS-MetadataExchange
9. WS-Security (not mandatory, only recommended)

What is available

Looking for DPWS implementations, at the time when experiments were done, the main players were:

1. ws4d [21]:
    - ws4g-gSoap, a complete C/C++ DPWS 1.1 stack
    - ws4d-uDPWS, a C stack for devices with extremely scarce resources
    - ws4d-JMEDS, a Java stack
    - ws4d-Apache Axis2, a java stack to be used with Axis2 platform
2. WSDAPI, Microsoft stack integrated into Windows since Windows Vista (some DPWS 1.1 features are missing)
3. .NET micro Framework, a .NET integrated DPWS stack

We decided to use the ws4d-gSoap stack, being the one really multi-platform in the group.

Let's make a player

The idea was to build a basic multimedia player (a **client** in DPWS jargon) exchanging messages and events with a central server (a **device** for DPWS) using DPWS.

The multimedia data stream was managed by a separate **rtsp** connection.

The player negotiates with the server the video to show and register its intention to be notified about certain events, specifically some information about train journey progress.

Development

The development initial phase was a little bit hard because of some slight incompatibilities between the software modules we chose and because of the time spent to fully overcome the identified development constraints.

The latter was mostly dependent on the fact that some of the sources had to be developed by hand because of the lack of an automated tool, so we had to design our prototype accordingly.

As shown in figure 3, from WSDL, two transformations had to be tweaked by hand to have proper gSoap files, before Makefiles took care of the remaining compilation issues:

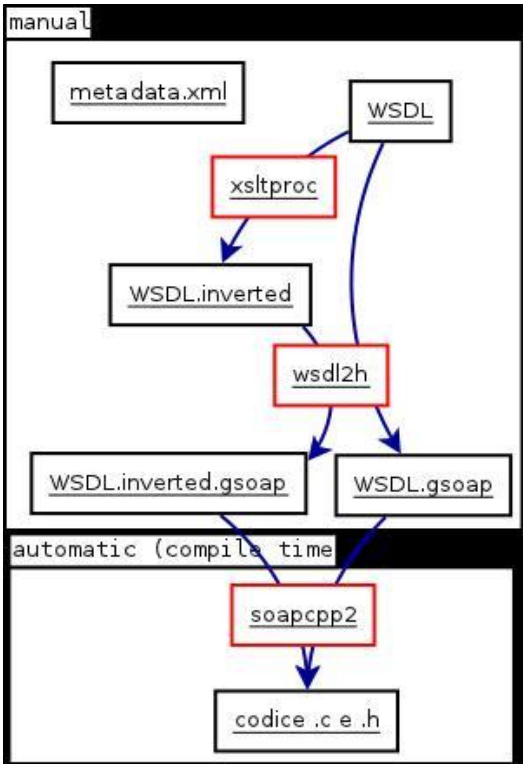

Figure 3 – Structure of the WSDL implementation

After this, the progress of the project was regular and we reached the expected results.

In the test development, we pursued and successfully achieved several aspects of interaction, specifically implementing:

- Device discovery
- Device profile request
- Event registration
- Message exchange
- Security

First results

In the end, the experimented technology proved to be effective and the following preliminary conclusions were reached, analyzing the achieved results (figure 4):

- Very promising technology with still some work to do to make it be fully consistent
- Some security issues still need to be addressed
- Chosen implementation is non-optimised for embedded systems but performed acceptably
- Most available implementations are not yet complete

- A streamlined development process is hard to be achieved with current tools
- To achieve interoperability at standard level, a big effort is needed to avoid incompatibilities

Figure 4 – Final result of the implemented multimedia application

5. Standardisation process

In order to achieve multimedia application interoperability, the envisaged solution, whichever it will eventually be, needs to be standardized. This is true at international level in order to avoid that digital multimedia services are implemented using mostly proprietary designs and technologies that, consequently, overlay conventional communication and control architectures implemented on trains according to standardisation and state of the art.

Furthermore, a standardisation of the envisaged solution is mandatory at European level in order to offer the harmonized support to the essential requirements and basic parameters reported in the Technical Specification for Interoperability (TSI) issued by the European Railway Agency (ERA).

Following these considerations, a proposal was submitted by the IEC National Committee of Canada to the attention of the IEC TC9 and a Survey Group on Multimedia was set in 2005. The results of this Survey Group encouraged the setup of a Multi Media Ad Hoc Group (MMAHG) in 2006.

In 2007, the proposal presented by the MMAHG was accepted by the IEC National Committees and the preparation of the IEC62580 series of standards was decided and initially tasked to the existing IEC TC9 WG43, in charge of preparing the new IEC61375 series for Train Communication Network.

In 2008, the IEC TC9 WG43 Convenor reported at the IEC TC9 plenary meeting in Kista on the heavy task of managing the preparation of TCN and Multimedia standards in one working group and proposed to set up a working group dedicated to Multimedia. IEC TC9 accepted the proposal and decided to set up the WG46 for the preparation of IEC62580, asking the WG43 Convenor to be also the convenor of WG46, in order to guarantee coordination between the two series of standards.

The task assigned to WG46 [22] is to standardise the general architecture for multimedia applications on board of trains in terms of ICT services orientated to passengers, crew, driver, operator and maintainer. Furthermore the task includes the specification of video surveillance and CCTV applications.

In order to use the state of the art multimedia technologies, some liaisons were set up with:

- TC100, in charge of standardising audio, video and multimedia systems and equipment
- ISO/IEC JTC1 SC29, in charge of standardising the MAF - Multimedia Application Format;
- TC79, in charge of standardising video surveillance and CCTV systems and equipment.

IEC TC9 WG46 produced the document for Part 1 - General Architecture and the draft was submitted to the IEC National Committees and the CENELEC National Committees. This means that it will be published as IEC62580-1 and EN62580-1 according to the agreement between IEC TC9 and CENELEC TC9X, called merging strategy. In order to facilitate the parallel voting process, CENELEC TC9X WG15 was set up, which is the mirror working group at CENELEC level of IEC TC9 WG43 and WG46.

The part which standardises video surveillance and CCTV is in preparation as well as the part which standardises the passenger orientated services offered by the Passenger Information System and Passenger Entertainment System.

6. Conclusions and perspectives for the future

Innovation is not only the introduction of fully new technologies and products but also the application of existing products and technologies to bring a significant improvement in terms of novelty of application area and performance level. In this view, the research work here described and the standardisation activity of IEC TC9 WG46 is producing innovation in the sense of applying state of the art products and technologies developed in other fields to the specific and very special field of railway vehicles, where environmental conditions and user requirements are challenging issues.

Such synergies between standardization and research, within the constraints of strategic policy and regulations, represent (figure 5) key factors in driving the evolution of railways towards a more open, competitive and user-oriented system, which will benefit our society.

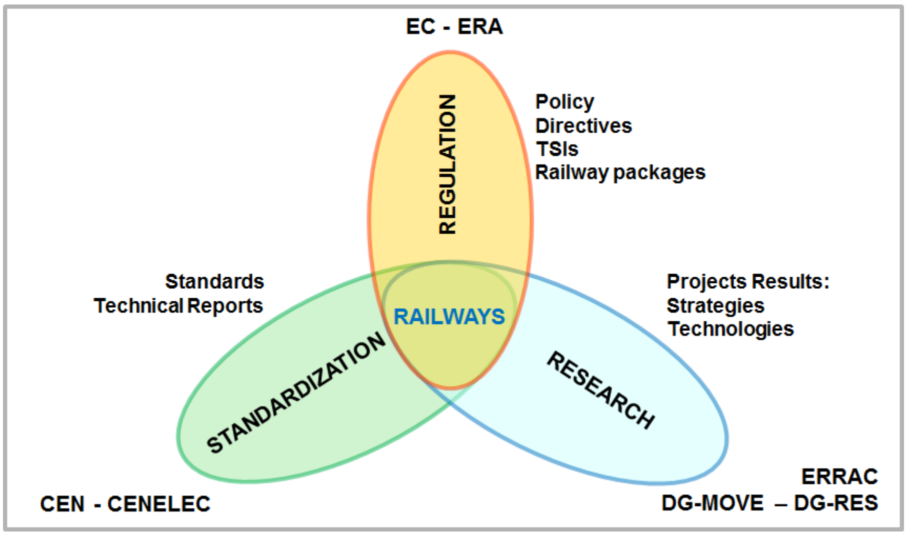

Figure 5 – Main drivers of railway evolution in Europe

Future products compliant with the envisaged standard solution will offer benefits, like easier commissioning, simpler system maintenance [23], lower life-cycle costs.

System integrators will integrate more easily multimedia subsystems into trains, as they will offer a compatible standard interface; maintainers will have the possibility to replace faulty or obsolete components with others, even coming from a different supplier, and reduce stock parts; operators will have a wider choice and will not be tied to a single supplier for each fleet.

An important benefit will be to lower entry barriers to market, allowing new companies (especially SMEs) to develop new products and easily integrate them within final systems. Moreover, they will not have to equip products with a range of different interfaces, according to choices imposed by each system integrator.

Finally, passengers and goods transport companies will experience better services, supported by a smooth information flow, and will be more keen to choose railways as their preferred transportation mode.

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