A Telematics Approach to Documentation on Railways

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Abstract: - Nowadays locomotive engineers yet have to carry printed documentation in a big and heavy bag. This situation involves poor accessibility and inadequate management of this information that hinder railway operations. A new telematics solution is proposed to address the problems derived from carrying this huge amount of printed paper. The solution is analyzed functionally, explaining its characteristics and outlining some technical aspects of its implementation. This thesis is inspired on a case study deployed at Euskotren, a railway operator in the Basque Country. During the experiments that were carried out, this innovative approach to documentation has proved to improve the efficiency of railway operations and in turn improve safety in railway operations.

Key-Words: - railway telematics library software HMI train documentation

1 Introduction

Railway operation involves several procedures that require being aware of a large amount of information. Particularly, although the train driver has to mainly keep his attention on the actual driving of the train, eventually he may have to undertake other actions that demand having available several kinds of information.

The sources of this information vary. This information can be learnt by all the actors involved in the operation, and this is the case of the most fundamental types of information, e.g. information regarding train driving such as the common maximum speeds, the meaning of semaphores lights, the procedure on stopping the train and opening the doors, etc. However, this kind of support: human learning, is reliable only when the information is used very often. On the contrary, these data tend to be forgotten or corrupted when they are not commonly used [6]. That is why, instead of relying on human capabilities, some types of information are usually provided printed on a certain support, so that it is accessible in the case of being required [18].

The need to eradicate paper from certain areas of human beings life has been satisfied incrementally since the irruption of electronic devices in day-to-day life. However, railways, as aeronautics, and those environments that are particularly reluctant to innovate on those elements that affect safety, tend to slow down the pervasion of telematics into their systems. Nevertheless, some outstanding projects [2], [3], [12] or [11] demonstrate that the benefits of telematics can be successfully incorporated to vehicles, keeping its operation even safer. Hence, this solution has been designed in close cooperation with the company Eukotren and its integration with railways operation has been gradually evaluated, so that the impact of it on safety can be tracked.

Currently, the sole support available for some types of information is printed paper. This is the case of the company Euskotren and other railway operators. And actually there seems not to be any other immediate solution. Therefore the solution explained next has been developed. This not only has been claimed by the railway operator mentioned: Euskotren, but by other authors as in [9] and [5] .

2 Printed documents onboard

When passengers see the locomotive engineer stepping into his cabinet, they notice that he often carries a big bag with him. What that bag contains, why and what are the problems derived from that? And the most important question: can this be improved so that the operation becomes safer and more efficient?

2.1 About this documentation

It is not the purpose of this article being an exhaustive reference (see [9]) about the description of the documentation carried onboard, but it is suitable to understand the type of information that justifies the necessity of this documentation as a support mechanism of the activities performed by the train driver. Thus, the main documents that are carried out by a train driver at Euskotren are exposed next. However, in other companies with different contexts and regulations other kind of documents might be carried. Basically, three types of information have been identified: manuals of the operation of infrastructure devices, maps of the route and regulations or protocols that establish how to deal with certain protocols in railways operations.

Manuals of the operation of infrastructure devices. For instance, a manual that explains how to operate an interlocking manually in the event of automatic operation failing; a manual that explains what the relays on board are and which ones should be reviewed in case a certain functionality (e.g. gates control) fails; or a manual explaining how to manually open the doors of the train when the electronic mechanism fails.

Maps of the route. Synoptics (see Figure 1) that contain traffic indications to help the driver know how to conduct the train at a given location; or how to accurately refer to a signal (what the signal number is) when a message about it has to be reported to the control room, i.e. these maps are used as an absolute means to identify the infrastructure elements by the operators in the control room, by the train drivers and by the supervisors.

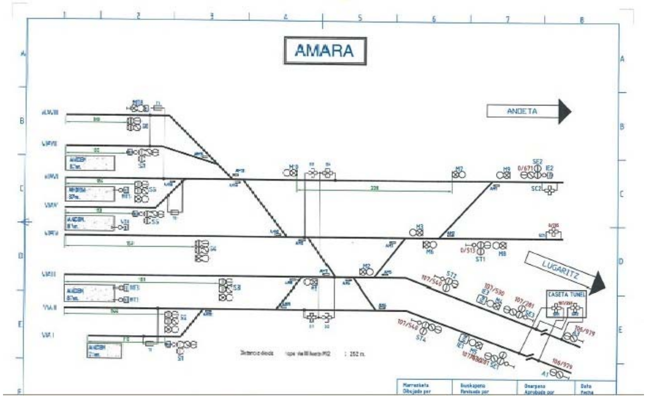

Figure 1 - Railroad synoptic

Regulations that establish how to deal with certain protocols in railway operations. For example, oral communications are accurately regulated [8] and, hence, certain verbal messages in a specific form are exchanged between the train driver and the control room. The way in which these messages are formulated and interpreted is codified and included in the documentation carried by the train driver. Obviously, it is expected that the locomotive engineer knows by heart how to use these messages; but, sometimes some doubts may arise and the purpose of these documents is to help him clarify these doubts.

2.2 Characteristics of the information

An analysis of these pieces of information has been made. It has been concluded that there are some characteristics that must be taken into consideration in any approach that intends to organize the management of it.

Position related information. The information contained in the documentation may or may not be related to the position of the train in the rail network. For instance, most of the regulations of railway operations are not position dependant; however, the synoptics of the railtracks at a train station are obviously related to a position. The relevance of this characteristic relies on the fact that, very frequently, position related information will be required exactly when the current train position is near the position associated with that information.

Vehicle related information. A similar situation occurs when it comes to the type of train vehicle that is driven. Usually, the fleet of an operator consists of several series of trains, each of which has a different manufacturer and has different equipment onboard. In consequence, some documentation is tightly related to the vehicle and its series number, e.g. which relays need restoring when a specific onboard mechanism fails or what the restarting sequence is for a certain electronic device.

Dynamicity and granularity. Data require being updated depending on the aspect of the railway operation they depend on. And this dynamicity is not homogenously distributed for every set of information. For example, maps may change frequently on a daily basis when there is an area in which some maintenance tasks are being undertaken; but it is probable that they will not change again in months once these tasks have been finished. In consequence, it is important to determine different levels of hierarchized and customizable granularity of the information that ensure the consistency of the whole documentation when updates are due and, at the same time, support selective updates at different levels.

Format. The information currently used includes images (vector graphics), schemes and plain text. The sources of this information are very diverse. Manufacturers provide the manuals to operate their devices; although, these manuals are updated by the maintenance department of the company when an improvement or a repair is done. The network operator creates and maintains its own documentation about internal regulations. The owner of the railway infrastructure provides the information about the infrastructure and its elements. In summary, heterogeneous sources for this documentation exist, and therefore the support for this information has to be as loosely coupled as possible and very flexible.

2.3 Problems derived from this situation.

Once the baseline of the content and the characteristics of the documentation carried by train drivers have been established and considering the framework that currently supports it: printed paper, several problems and disadvantages are easily observed. The next are the main ones that motivated at Euskotren the promotion of a new electronic framework in its railway operations.

Accessibility: searchability. Handling loads of papers is not an easy task. Even though these papers may be ordered and classified and the train driver may be familiar to this ordering, looking for a certain solution associated to a specific rail station may be difficult. It is even more difficult if the information is not classified by rail station but by manufacturer or by the owner of the infrastructure, i.e. only one single criterion is possible for classifying. Regardless this classification, it is obvious that turning pages is not the quickest way to search information.

Accessibility: readability. The way in which printed information is shown and read is not customizable. The way it is printed directly conditions how the train driver reads it. Therefore, different handicaps affecting the reading process become important, for example, the light available, the distance from the eyes to the paper, the clarity of the printing, etc.

Loss of attention. As a consequence of the previous two inconveniences: poor searchability and readability of the information; the driver is required to focus a significant percentage of his attention in tasks different to main railway operations, such as, train driving, passenger control, communication with the control room, onboard device control, etc. This results in a higher probability of failure on performing these tasks [1].

Distribution management. Train drivers change very often the routes in which they work. It is frequent that a driver has to work in several routes during a single shift. Moreover, a driver will drive different models of vehicles during his shift. Equally, a certain model will be used at different routes depending on the availability of vehicles and the demand of the operation. As it has been exposed, the information is sometimes position and vehicle dependant. This means that the driver will have to be changing continuously the documents he handles because of changes in the routes and the vehicle. A complete distribution system is required to ensure that at a given route with a certain vehicle the information available is the right one. Instead of appropriately synchronizing vehicle, route and driver on distributing the documentation; this situation is usually addressed by including the information for every route and every vehicle in the documentation package provided to the driver. An approach that, in turn, makes readability and searchability even poorer.

Update management. When the information has to be updated, it has to be reprinted and redistributed. This process has inherently some costs that make it only justifiable when a significant number of updates are due. In the mean time, the updates are usually reported in the form of annexes that break the order of the documentation. This fact implies that the documentation will not always be as up to date or, at least, as coherently ordered as it would be desired.

Environmental issues. Environmentally speaking the current framework is not a scalable solution. The more the activity of the railway operator grows, the greater is the number of train drivers employed and the larger is the area covered by the routes offered, and consequently the more paper will be printed. Along the same line, for each update that becomes necessary, these papers have to be reprinted again. Obviously, this is an expensive, non scalable, framework both economically and environmentally.

3 An electronic library onboard

A project consisting of several telematics solutions to improve safety in railway operations has been developed in a joint effort of the University of the Basque Country and the railway company Euskotren. This project has resulted in the development of an infrastructure for implementing these telematics solutions as well as the solutions themselves.

This approach to improving railways operations has already been introduced in [14] focusing on the notion of how a telematics framework can improve railway operations. Herein one of these solutions is thoroughly discussed: the onboard electronic library, which is part of an integrated train driver information system. The onboard electronic library addresses the problems motivated by the current documentation framework for train drivers that has been presented.

Next lines describe the foundations of the infrastructure required for the implementation of an onboard electronic library. The functional description of this solution follows next and, finally, some technical guidelines concerning the implementation of it are enumerated.

3.1 IT infrastructure

To implement a telematics solution the very basic requirement is an IT (Information Technology) infrastructure. In railways this infrastructure is not commonly deployed in the rolling stock. Therefore, the first step is to deploy it.

Two basic aspects have to be solved by the IT infrastructure: processing capabilities and communication networks. They have to be deployed both in the control room and in the rolling stock. The latter is rarely fully available, whereas some processing equipment may be installed; it is rarely interconnected with the control room

Usually, it is common to find onboard already installed legacy devices and networks. However, these elements constitute a large variety of devices and networks that have been gradually installed when specific functionalities have been required by railway operation.

Consequently, the common case is to find different manufacturers and a great lack of interoperability. In spite of that, some times it is worth to balance the possibility of integrating the functionalities provided by these systems in the new IT infrastructure; alternatively, new elements implementing these functionalities may be installed. The former requires the implementation of intermediate or proxy functionalities and its viability must be evaluated for each element considering both performance and implementation costs.

Figure 2 outlines the infrastructure deployed in the research studied in this article.

Amongst the processing capabilities, there is a service that has to be available for the rest of the processing devices, i.e. the positioning service: a source of information that provides the train position, kilometric point (KP), within the railway network. It has been proved (both in this research and others [7], [10]) to be possible to implement this service in a cost-effective manner by means of three sources of information: (1) a GNSS (Global Navigation Satellite System) device that computes the longitude-latitude coordinates and interfaces with a processing device, e.g. a Human Machine Interface (HMI), by means of an NMEA (National Marine Electronics Association) serial interface; (2) a local database with railway network maps to map the GNSS information to real train positions; and (3) a girometer that improves the reliability of GNSS on resolving the position after a bifurcation of the track. These three sources of information can be embedded in a final processing device (PD) and easily installed onboard of rolling stock of any kind.

With regard to communications, the infrastructure consists of communication channels that cater for monitoring and control channels interlinking locomotive engineers, onboard telematics systems, systems at the control room and dispatchers in the control room.

The communication architecture proved at Euskotren is as follows (see Figure 2): onboard a former industrial network (N1) (e.g. TCN) is interlinked with a new OPC/Ethernet network (N2) by means of a gateway. The PD is placed in this second network to which the Onboard Communication Router (OCR) belongs. Depending on traffic requirements and the complexity of this second network, PD and OCR may be integrated in a single device. The OCR connects devices in N1 and N2 with control room devices (CRD) in the network at the control room (N3). The physical link between the OCR and the entry router at N3 is implemented in two manners: by means of an 802.11 wireless network (WN1) for high data rate and non-real-time communications; and by means of a VPN (Virtual Private Network) on a GPRS/UMTS/HSDPA access network (WN2) for low data rate and real-time communications. WN1 is mainly available at rail stations and WN2 is available all along the railway network (apart from certain known locations where wireless coverage may be poor, this can be requested to be sorted out to the telecommunications operator though)

The implementation of each of these processing and interconnecting elements may differ. In [12], [11], [10] and [4] alternative implementations are discussed. They also address the development of infrastructures with similar characteristics but in a way different to the one proposed here.

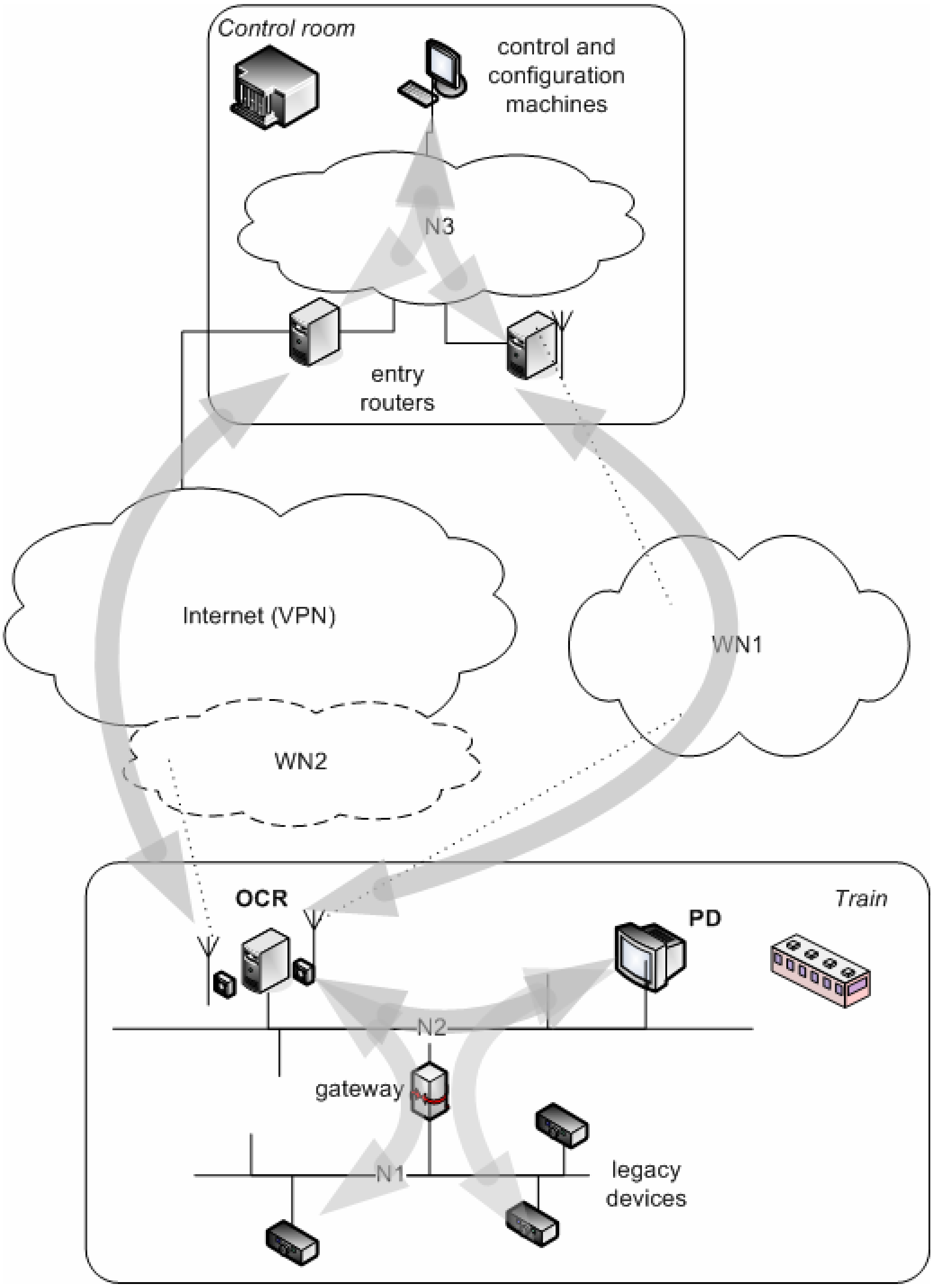

Figure 2 - IT Infrastructure

However, there are a few aspects in which the implementation outlined here outperforms these other projects:

- The deployment of the infrastructure explained can be implemented “on top” of the existing communication and positioning systems instead of being a replacement. It does not interfere with the existing infrastructure, but collaborates with it. It makes possible new parallel monitoring and control processes that, in turn, increase the safety in railway operations because they improve the availability of the infrastructure.

- No major trackside infrastructure is required, avoiding important deployment and maintenance costs of the new infrastructure. Occasionally, tunnels and special areas may require the installation of GNSS repeaters and/or telecommunication antennas. Consequently, every infrastructure element is physically accessible (whether onboard or at the control room) and any failure that may affect the operation can be easily sorted out, i.e. high maintainability. Additionally, this aspect means that reaching interoperability between railway networks becomes a more practical and economically achievable objective.

- Rolling stock of all kinds is suitable for being equipped with this infrastructure. Even maintenance and repair workers could potentially carry with themselves the positioning and communication devices as suggested in [13] and in [15].

- There is no assumption in the design of this infrastructure that limits its suitability to a certain kind of railway network or a certain type of railway traffic. As a consequence it allows for safety improvements at all sorts of railway services: high-speed (see [16]) inter-european railways, low and high density networks, metropolitan, provincial, national networks, etc.

3.2 Functional description

Three main functionalities have to be addressed by the solution (see Figure 3): (1) the library data model, (2) the configuration application and (3) the visualization application.

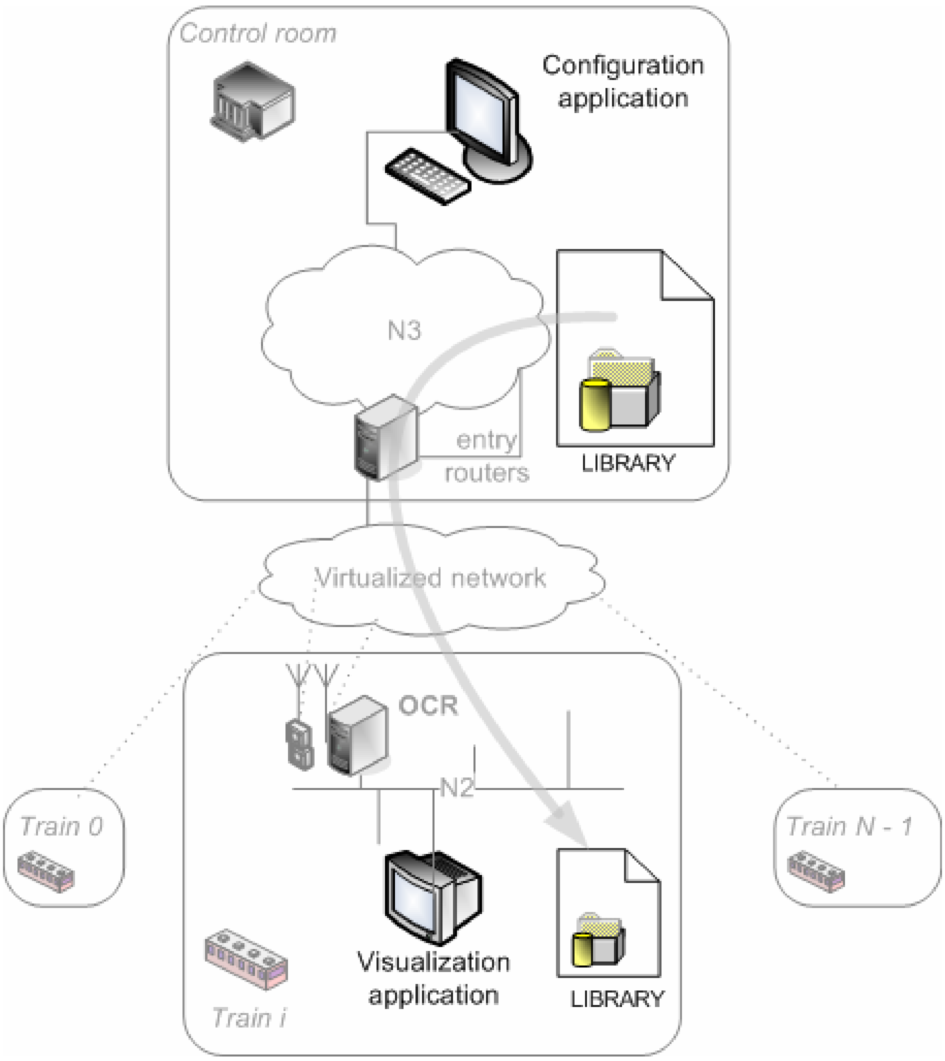

Figure 3 - Electronic Library functionalities

3.2.1 The library data model

The data model determines how the information described in 2.1 is going to be logically handled by the applications. Two aspects of the information are considered:

- Railway Operation Information (ROI): involves the digitalized representation of the aforementioned information.

- Visualization Information (VI): includes the information required to represent how the ROI is going to be visualized by the visualization application.

The main requirement for the data model is that it must be as flexible as possible in two aspects:

- To support an interoperable format of digitalized information for the ROI.

- To provide the capability to customize the way in which the information is visualized to the train driver according to different evolving circumstances.

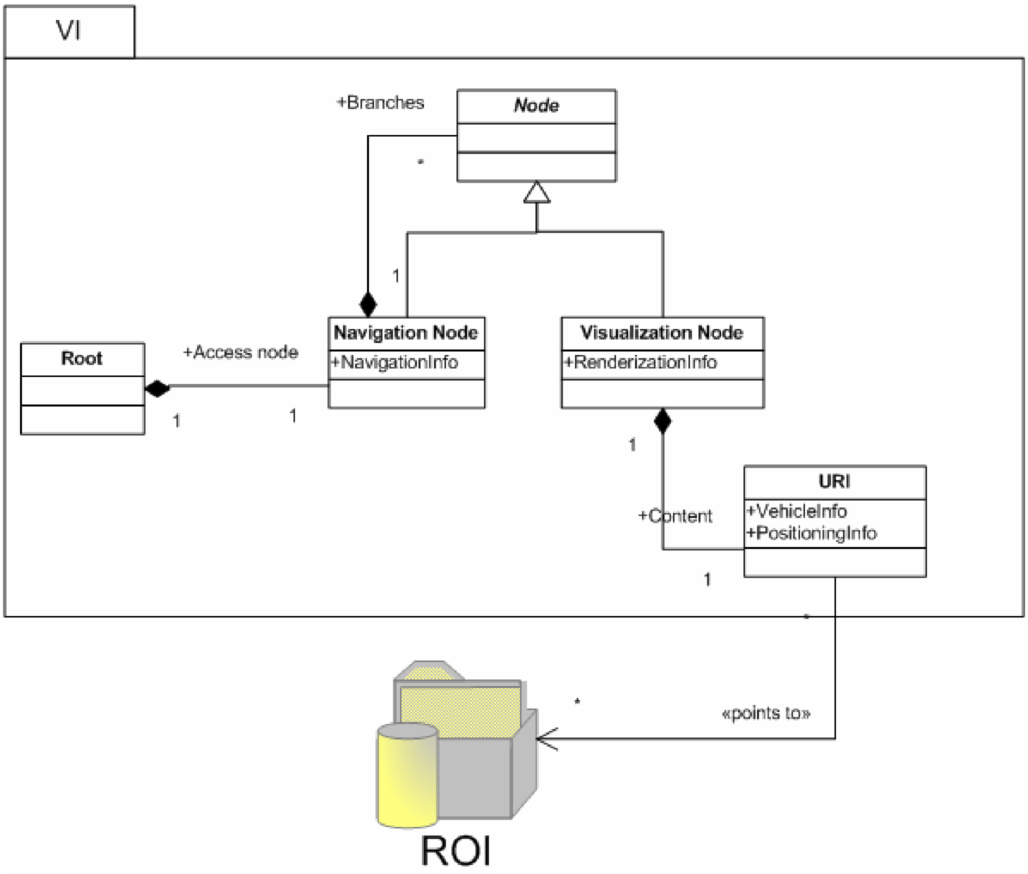

Figure 4 – Library data model

Figure 4 illustrates the UML data model that caters for the flexibility due. It shows the relationship between the VI and the ROI. It can be seen that VI is a layered hierarchy of nodes containing the information used by the application to implement the user navigation through information. Some of these nodes will render the content at the ROI repository pointed by a URI that is associated to a given position and information about the train vehicle.

Note that the way in which VI and ROI persistency is implemented is not determined here to let this solution be as platform independent as possible and highlight the fact that this is not a constraint for the validity of the solution. However, in 3.3 some guidelines corresponding to the actual implementation of this case study are introduced.

3.2.2 Configuration application

The configuration application (see Figure 5) is responsible for three tasks:

- Building the ROI repository that is distributed to each train unit, i.e. creating the digitalized pieces of information and uniformly persist them at a given storage system (e.g. a database or a file system)

- Creating the VI that marshals the ROI units in a way suitable to the train driver. It is suggested that the visualization component used in the visualization application is jointly used in the process of creating the VI so that the user that builds the VI can predict how the information will be shown to the train driver.

- Scheduling the distribution of updated VI and ROI to specific train units. The actual implementation of this information distribution is out of the scope of this article. But it can be outlined that it is an Uploads Management System (UMS) that according to some metadata intelligently distributes the given payload (VI and ROI) to the selected train units. The UMS provides incremental distribution of persistent elements (a file system element), what in turn improves the scalability of the distribution system.

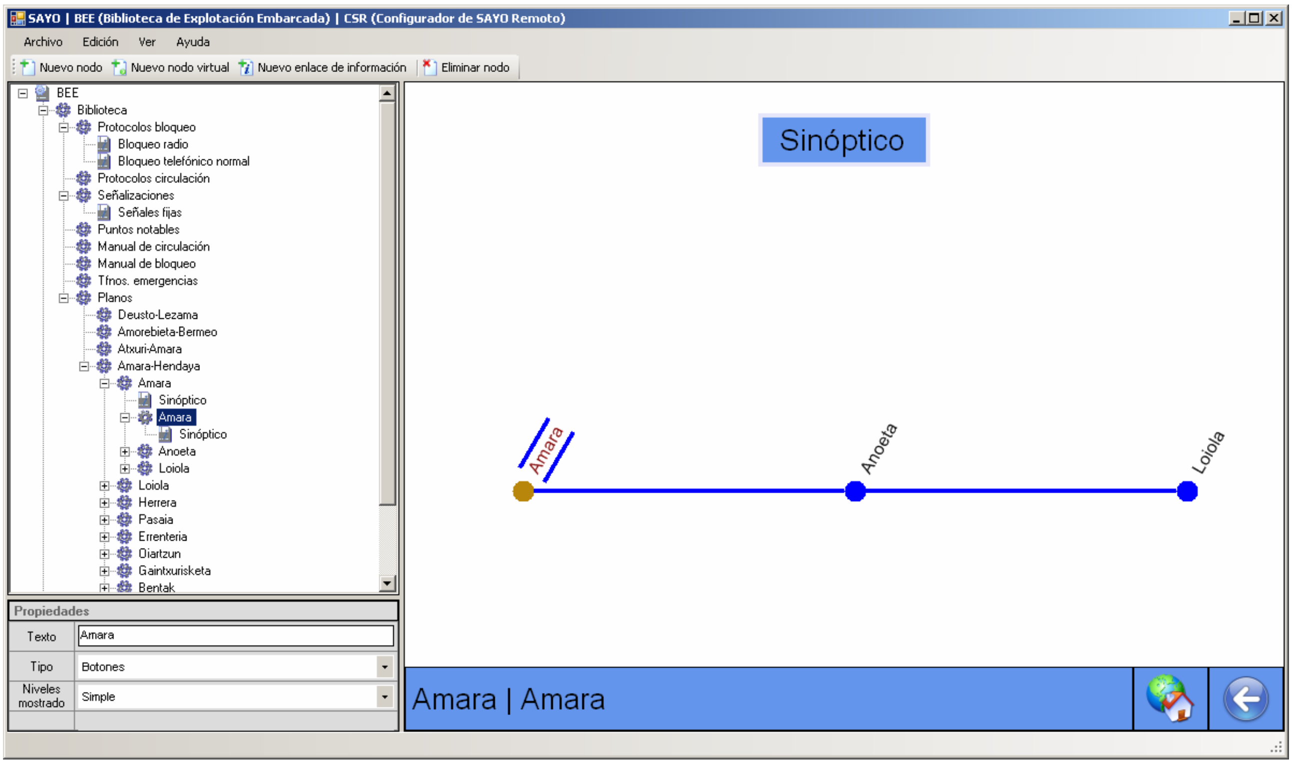

Figure 5 - Configuration application snapshot

This application is executed at the control room in a desktop machine by a user with specific knowledge about the data contained in ROI and about ergonomic aspects affecting the train driver during railway operation.

3.2.3 Visualization application

The visualization application is executed in an onboard HMI and is integrated within a more complex software system implementing additional safety solutions (see [14]). Two are the main tasks that are executed by this application:

- Rendering the information contained in the ROI according to the information described in VI and to some characteristics that are particular to the HMI in which the application is implemented (i.e. the implementation for a touch screen will be different to that for a button based HMI) Equally, very specific requirements for this application may be raised by ergonomic experts [17] and they must be considered (e.g. the combination of colors used, the controls provided to browse the information or facilities to zoom the documents) In overall, the requirement is making information accessible: readable and searchable.

- Coordination of the railway operation and the rendering of the information. This coordination consists of implementing the policies for the integration of this application with the train driver's operations. For example, in the case of position related information being accessed, the application will automatically show those ROI elements that refer to positions nearer to the current train position. Another example, the application will restrict the access to some low importance information while the train is moving and it will only allow the train driver to access it when the train is fully stopped to prevent him from losing attention on train driving.

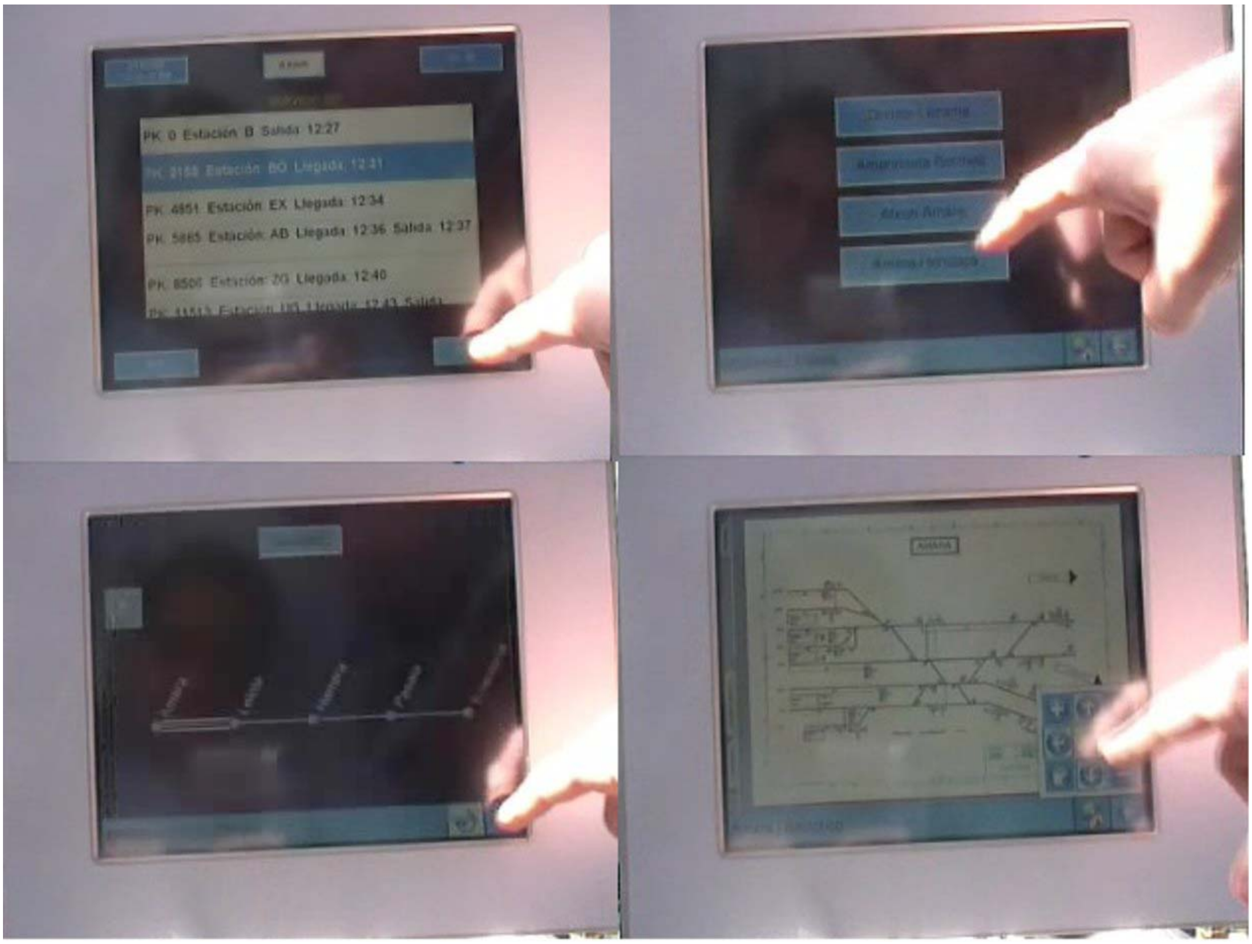

Figure 6 - Visualization application snapshots

3.3 Technical aspects

The functionalities just explained can be implemented in several manners. Next some technical considerations regarding the experience at the case study motivating this article are enumerated.

- ROI persistency: the pieces of information contained in the ROI come from several sources and a flexible mechanism for their digitalization must be used. Printing documents into PDF formatted files has proved to be an adequate (loosely coupled) mechanism for persisting the documentation. These files are structured in a file system hierarchy as desired by the final user. Another option would be to store them in a database but this alternative requires a DBMS (DataBase Management System) which otherwise is not required.

- VI persistency: the implementation of the data model visualization persistency has been achieved by means of an XMI (XML Metadata Interchange) file. This proves to be the best alternative when it comes to interoperability and potential reuse by other systems in the future.

- Non-mechanic storage elements are required onboard due to the intolerance of these elements to vibrations. In consequence, solid state Compact Flash memory has been used. It has to be taken into consideration that the number of writing operations is limited and this is a factor the UMS accounts for by minimizing the number of writings.

- .NET framework has been used both in the configuration and the visualization system. The HMI was running an XP Embedded operating system. The performance of this environment has proved to be excellent.

- The rendering functionality has been implemented as a .NET component (any other encapsulation mechanism available at other platforms is valid as well) so that it can be reused both in the visualization application and in the configuration application.

- The communications protocol used for the distribution of the library repository was both FTP and SMB/NetBIOS.

4 Conclusions

A solution to the problems motivated by the use of printed paper for the documentation carried by train drivers during railway operations has been proposed. This solution has been proved in a real case study with the railway operator Euskotren in the Basque Country.

This article focuses mainly on the functional description of the solution, because the technical aspects of its implementation are not a condition to attain the benefits of it.

This solution eases the process of updating and distributing the information required by locomotive engineers. At the same time, it allows for an ergonomic integration of the information with the train operation. The safety of the operation is consequently improved because the driver does not have to deal with the inconveniences of printed paper and the information is more accessible.

With regard to future work motivated by this research, in spite of the successful of the primary validations carried out, massive application of this solution demands further tests and an analytical framework to evaluate the impact of telematics on the safety of the processes developed by the personnel of railway operations. Equally, the IT infrastructure developed is a key factor for new promising telematics solutions that can improve safety and performance in railway services. But its implementation requires being formally described. It has to be validated and contrasted against the ones proposed by other authors (see 3.1). And should expressly consider incipient technologies, capturing the best of them all and enabling an off-the-self, standardized, railways IT infrastructure for future projects.

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