Towards a Service based on “Train-to-Earth” Wireless Communications for Remotely Managing the Configuration of Applications inside Trains

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Abstract. This paper describes a distributed service based on “train-to-earth” wireless communication, which is able to allow maintenance engineers to remotely monitor and update the configuration of the applications running inside a fleet of trains. It is a very useful tool that avoids engineers to move from their offices to trains for doing the maintenance tasks. This service is the result of five years of collaboration with a railway company in the north of Spain. Moreover, it represents the following step after the implantation of an innovative "train-to-earth" communication architecture in this company. Today, both the communications architecture and this service are being tested within the installations of the railway company with successful results.

Keywords: software configuration management, remote engineering, train-to-earth wireless communications, distributed application, railway

1 Introduction

Advances in communication technologies and their implantation costs reduction are enabling the use of wireless technologies in the railway industry. This use is progressively growing motivated by the fact that more and more new generation services are emerging which need to exchange information between trains and ground centres [1].

Traditionally, railway services have been oriented to exploitation. However, the progressive establishment of wireless “train-to-earth” communications is becoming a key factor for developing various digital services that will ease daily work in the rail sector, and will increase the quality of the service provided to the users [2].

One of the main targets of applications running inside the train is to provide information to facilitate the work of the driver. Usually, they need to use data generated in the ground centre. If this data changes, it needs to be updated inside the train. In addition, there are terrestrial applications that need to use data generated by some on board applications. Thus, it is necessary to design distributed solutions and tools for exchanging information between trains and the control centres in a synchronized way.

This paper presents a *Remote Applications Management Service (RAMS)* that is part of the results of the work made during the last four years alongside a regional railway company of Spain. It defines a particular service that allows the remote management of on board applications (upgrade, download and deletion of its information), and it is integrated in a general purpose wireless connectivity architecture that has been established by this company for enabling "train-to-earth" communications [3]. The main objective of RAMS is to improve the maintainability of systems and applications with are running inside the train.

The paper is organized into the following sections. The second section includes a brief description of the key functional requirements of the service developed. The third section details its architecture and design issues. The fourth section presents the results of the tests made in order to validate its performance. To close, the fifth section of the paper establishes the main conclusions of this work.

2 Functional Requirements

Traditionally, the maintenance of the train on board software systems has been completed through wired communications. Engineers had to go from train to train and connect to terminals to perform the unloading and loading of data of the applications running inside the train.

Regarding to services oriented to the driver or train staff, one of the most relevant one to develop would be a utility for downloading and/or updating documents with relevant information for them. This information would be coming from an application from the outside. This system would be very helpful because the driver could obtain updated information on any item he would like (from route itineraries to security protocols) fast, thus facilitating his work. This utility would free the driver from the burden of carrying information on paper, and even allows the on-line notification of such documentation updates.

Therefore, the main functionality of the service presented in this paper is to control the update of the information used by applications running on the train terminal (for example track flat information or supporting documentation for the driver generated by the ground information systems) as well as downloading and deleting information generated by some on board applications (for example log files) remotely from the ground centre.

The solution consists of two software systems, one for the ground centre (Terrestrial RAMS) and the other one to be deployed in all train terminals (On Board RAMS). Thus, the terrestrial RAMS system is installed on ground centre, and it will be responsible for managing the status of all applications in each terminal. On the other hand, on board RAMS system will handle update, download and deletion requests made by the terrestrial RAMS system. So, **terrestrial and on board RAMS functionality** involves these issues:

- Knowledge about the configuration information (files which conform it) for each application installed on each train terminal at any time (keeping a history of changes in each application's files over time). As well as about the files and/or

documents currently used by these applications which can be updated, downloaded and/or deleted. This information will include: version, creation and last update date, update status (pending or not), etc. This management is done through a repository of information in a database.

- Management of information (files) of all current applications runnning in the train.
- Query management about the status information of the on board applications.
- Integration with the "train-to-earth" wireless communication architecture via heavy communications scheme (see section 3).

3 RAMS Architecture

To describe RAMS architecture, it is important to point out some concepts related to the "train-to-earth" communication architecture [3] in which is integrated. Thus, the adopted wireless connectivity architecture distinguishes two communication types:

(1) "Light" communication: this type of communication is for the transmission of small volumes of information (few Kbytes) and with high priority. In general, information that has low latency (milliseconds or a pair of seconds) and needs to be transmitted exactly when it is generated or acquired (for instance, the GNSS location of a train, or a driving order to the train diver).

(2) "Heavy" communication: this type of communication is tied to the transmission of large volumes of information (in the order of Mbytes) and with low priority. The importance of this information is not affected by the passage of time, so it doesn't need to be transmitted at the exact time it is generated.

Therefore RAMS application is integrated with this connectivity architecture via *heavy communication* scheme since it involves the exchange of large volumes of information that do not require real-time communications. Heavy communications purpose is to provide a way of enabling broadband communications which is suitable for the railway, due to the fact that a number of WiFi networks have been settled in places where the trains are stopped long enough to ensure the discharge of a certain amount of information (stations in the header that starts or ends a tour, workshops and garages). In this way, we can say that the WiFi coverage is not complete, but it is important to say that broadband communications are designed to update large volumes of information, which, theoretically do not need to take place in real time.

To manage heavy communications, this architecture defines the *Broadband Communications Manager (BCM)* [4]. The BCM is a system that arbitrates and distributes shifts to communicate terrestrial and train applications; in this way, the terrestrial applications request a turn when they want to establish a heavy communication with a train. This distribution shift is managed on the basis of the state of the train connection to a WiFi network (known at all times) and a system of priorities, which are allocated according to the terrestrial application that wants to communicate with the train.

Hence, when the terrestrial RAMS generates tasks which involve downloading or uploading data from and to trains, it has to communicate with BCM. In this case, BCM arbitrates communications between terrestrial and train RAMS subsystems. For proper integration with BCM, RAMS (more specifically the terrestrial one) shall be compliant with the protocol of communication established by this management entity.

At this point it is important to point out that BCM does not interfere between final applications communication, it only participates arbitrating the establishment of the communication between them. The Fig. 1 shows RAMS architecture and its integration with the "train-to-earth" wireless communication technology.

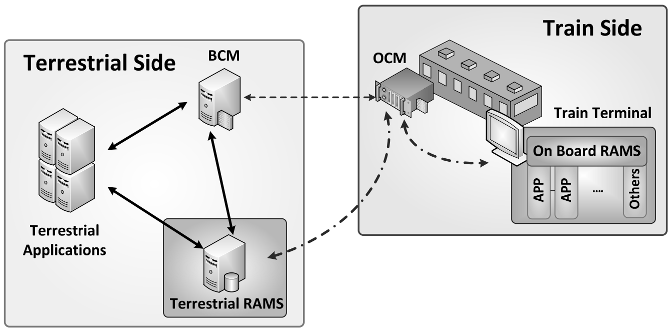

Fig. 1. RAMS and how it interoperates with the "train-to-earth" communications infrastructure: Broadband Communication Manager (BCM) in terrestrial side and On board Communication Manager (OCM) in train side.

As Fig. 1 shows, RAMS is divided into two distinct subsystems (Terrestrial RAMS and On Board RAMS in each train), which are divided into different modules that provide the previously described functionality (Fig. 2).

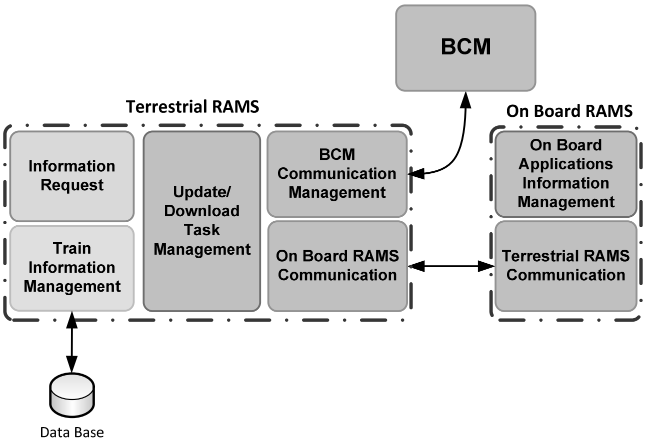

Fig. 2. RAMS architecture and its functional modules

With respect to the final communication between terrestrial and on board RAMS, there have been defined different scenarios depending on the type of tasks to be served. All of them have in common that the first message sent is a compressed and encrypted file that contains a XML document describing the task at hand (in addition to the XML, some tasks also attach all the files concerning with the task).

3.1 Terrestrial RAMS

Thus, the Terrestrial RAMS is divided into five functional modules which are described below:

- **Information Request.** This module allows the user to request different information managed by the RAMS (boarded application files' information, scheduled tasks' information, etc.).
- **Train Information Management.** Terrestrial RAMS is designed to manage the information of the applications running inside the trains. So, Terrestrial RAMS contains a similar information organization to the information loaded on each train, as a mirror and stored in a database repository, so that with each new modification made in one of the trains, such changes are reflected both on terrestrial side and in remote (train side).
- **Update/download Task Management.** This module aims to enable update and download tasks related to applications running inside the trains. These tasks could be launched in a moment or be programmed as periodical tasks.
- **BCM Communication Management.** This module is responsible for managing the interaction with BCM and implementing its protocol.
- **On Board RAMS Communication.** The wireless communication between terrestrial and on board RAMS is done following the heavy communications scheme which is included in the wireless connectivity architecture that we mentioned before. This communication will be carried out though WiFi networks placed in stations, workshops or carports. Anyway, there is also the possibility of communication with the trains terminals on a wired mode (with a laptop for example) if there is an anomalous event that avoids communication via WiFi. This module is responsible for implementing these point to point communications based on RAMS specific protocol.

3.2 On Board RAMS

The on board RAMS is divided into two functional modules. Their functionality is described below:

- **On Board Application Information Management.** The core of this module is an embedded FTP server that will manage all existing files in the train terminal. We opted for the use of an FTP server that will be used locally (not able to access it remotely), because it is a widespread technology in file management [5].
- **Terrestrial RAMS Communication.** This module responds the terrestrial information update and downloads requests (because communication between terrestrial and on board RAMS will be always initiated by the terrestrial side). It implements the RAMS specific communications protocol, enabling point to point communication with the mirror module in terrestrial side.

4 Functional Test Scenarios

The RAMS is currently being tested within the infrastructure of EuskoTren, a railway company in the north of Spain. These tests are carried out within the installations of this company, using a new generation train (its manufacturing was finished this year) equipped with the technology needed to hold train-to-earth communications, being the BCM a part of it.

BCM has been installed on a dedicated server for its work, and is located in a local network designed to communicate it with different deployed “terrestrial” applications. Today we can find two of these services, also in test phase, relying on the BCM in the local network installed. One of them is the described RAMS. In the case of the train, it has been installed a WiFi network in the station, so the OCM can connect to it.

In this way, the terrestrial RAMS has been deployed in a PC that is in the same local network in which has been installed the BCM, whereas the on board RAMS has been installed on the terminals of the train that has been selected to realize the tests.

When running the tests, we define two basic scenarios: (a) update task and (b) download task. Their design is shown in Fig. 3.

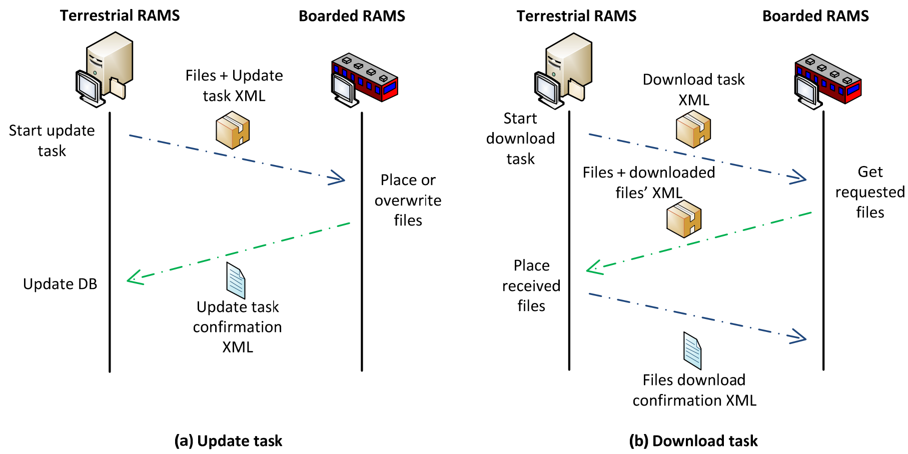

Fig. 3. Update (a) and Download (b) tasks' flowchart

4.1 Update task

Terrestrial RAMS allows the user to configure tasks related to update information running inside the train terminals. These tasks can involve the updating of a certain application files or documents that are accessed by the train driver.

As shown in the Fig. 3, when user configures an update task indicating files to be updated (or created), the terrestrial RAMS generates a compressed and encrypted file that contains a XML document describing the update task and the files selected to be updated on the train. Then terrestrial RAMS sends this compressed file to the on

board RAMS which responds with a confirmation message indicating if the task has been completed successfully.

Thus, to test the RAMS, there have been tested several scenarios: update and deletion of selected files which belong to an on board application, and remote loading of entire applications inside the train. All of them have had successful results.

4.2 *Download task*

Terrestrial RAMS also allows the user to configure download tasks concerning with information of the applications running inside the train terminals. These tasks can involve file downloads (logs or other applications files) or on board application file system status requests. These status requests allow the terrestrial RAMS to identify which is the version of applications files that are in train terminals, allowing the update of them if it is considered as necessary.

As shown in the Fig. 3, when user configures a download task (file list download or status request), the terrestrial RAMS generates a XML document describing the task. This is compressed and encrypted in a file and sends it to the on board RAMS. When on board RAMS receives download task information, generates a compressed an encrypted file that contains requested files and a XML which describes the information of these attached files, and sends it as a response to terrestrial RAMS. Then, terrestrial RAMS checks the received information, and responds with a confirmation message to the on board one indicating if the task has been completed successfully.

Therefore, in order to test RAMS download functionality, there have been tested several download tasks related to different scenarios: download of log files generated by on board applications and status requests of their configuration. All the tests have been performed successfully.

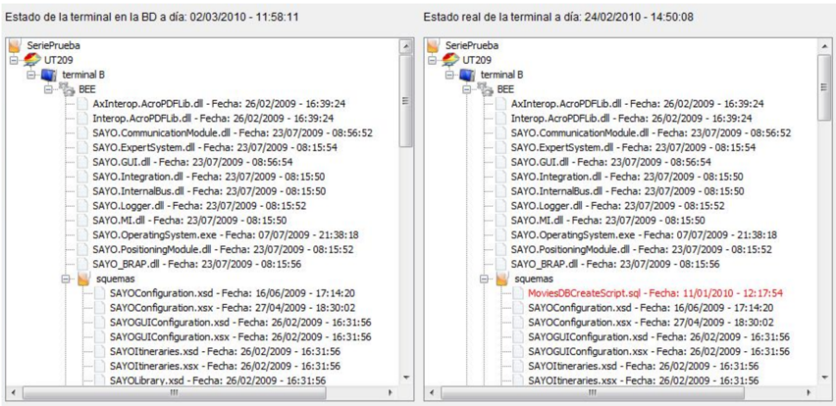

Fig. 4. Utility for analysing differences between applications configurations (train / ground centre). It is launched as result of a status request made over a specific train.

The Fig. 4 shows the result of a train terminal status request. We can see two file and folder trees. The tree on the left shows the updated terminal status that is saved on

the database of terrestrial RAMS and the tree on the right shows the real train terminal status. The database status is the updated one that should be in terminals on trains. So, when user configures a train terminal status request, terrestrial RAMS compare the real status of applications on terminals with the status stored on the terrestrial RAMS database. In addition, terrestrial RAMS highlights the differences between these two status trees (missing files, version differences, etc.), giving the user the option to update or delete files if it is required.

5 Conclusion and future work

Wireless communications are increasingly being adopted in several vertical domains. This is the case of railway industry, where these communications represent a key means to establish connectivity between trains and ground control centres. Moreover, this "train-to-earth" communications has become a requirement for developing a high number of digital railway services which could improve the way in which railways operators work.

This paper describes one of these services: a Remote Application Management Service (RAMS) based on "train-to-earth" wireless communication, which is able to allow maintenance engineers to remotely monitor and update the configuration of the applications running inside a fleet of trains. It means, to load the set of files which conform an entire application (deployment of a new application over a train), to check the status (versions) of their files and to update/delete specific files of an on board application, storing the history of all the changes made. It is a very useful tool that avoids engineers to move from their offices to trains for doing the maintenance tasks.

In this moment, our efforts are focused on adopting the web paradigm in order to become RAMS as distributed service which is accessible via a web browser. It is a very interesting challenge because it enables that the tool is hosted and administered by some technological provider company, being able to be used remotely and concurrently by several railway operators.

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