Satellite Enabled ITS Services for Cars

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Abstract

The SafeTRIP project targets the demonstration of a new satellite communication capable ITS system in real-life situations. The integration into a vehicle and testing of all related technologies in the field is a challenging task. In this paper, we present the journey that was undertaken by the SafeTRIP consortium from conceptual designs to deployment for the purposes of field trials and proof-of-concept. The paper begins by describing the steps taken to facilitate early software development and reproducible integration results. Next, as many components of the system were developed separately, a carefully orchestrated integration had to be performed in a lab setting. The last leg of the journey consisted of moving the integrated system into multiple vehicles at two test sites, accompanied by system tests and pilots. This transition has proven to be one of the most interesting and challenging aspects of the journey. We believe that our approach, findings and recommendations would be useful for the design of commercial platforms and services that exploit satellite communication and targets the mass market.

Keywords:

Satellite communication, broadcast, design, deployment, field trial.

Introduction

Satellite-based communication systems for use in homes [1] and commercial vehicles have been adopted by consumers in many parts of the world. The SafeTRIP system is based on a new satellite communication system supporting two-way communication. Using S-Band (2GHz) allows the use of small antennas and easy integration into the car combining the satellite system with terrestrial communication links. The SafeTRIP platform [2] supports a number of services designed to meet the needs of individuals [3] which are related to safety, navigation, security, sustainability and infotainment. Among others, these are: emergency call with video support (based on pan-European eCall model), stolen vehicle tracking, road alerts, collaborative road alerts, driver alertness and info explorer.

Background

The SafeTRIP project aims to develop an open platform and demonstrate its benefits through a number of complete end-to-end ready-to-deploy services - improving road safety, mobility and environment protection for passenger vehicles. The proposed services are primarily targeted to address the needs of individuals travelling by road - i.e. drivers and passengers of cars and coaches. The SafeTRIP platform is composed of on-board items aggregated into an On-Board Unit (OBU), central items (Hub, Network Control Centre) and distributed items (Service Enabling Platform). A smart middleware software running both on-board and centrally, provides an abstraction layer to the services, making the SafeTRIP platform capable of integrating alternative communication technologies (such as 3G-4G) and of supporting development and integration of third party services. The SafeTRIP system (Figure 1) uses both satellite communications and alternative ground networks in a fully interoperable and integrated approach. This combination has a number of unique features that, together with the intrinsic safety and security characteristics of the satellite-based approach, make it the most suitable telecommunication technology for transport systems.

The SafeTRIP project, a project funded within EU-FP/ research program, covers the development of a prototype useful for field experiments and demonstration of the key features. Special attention was drawn on the overall software architecture and the definition of clear interfaces.

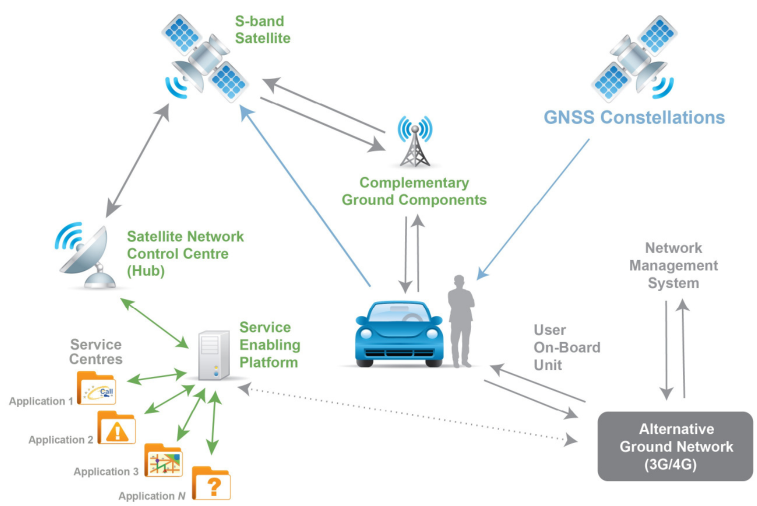

Figure 1 – SafeTRIP System Overview

The development phase

This phase was guided by the architectural design [4] that was formulated based on the extensive user requirement capture undertaken at the beginning of the project. While some components considered in the architecture were available commercially, the heart of the system – the SafeTRIP OBU – had to be developed using an industrial lab PC. In order to facilitate both the development and integration of the applications that would eventually be deployed on the OBU, several steps were taken.

Virtual Prototype

The general approach of the Virtual Prototype (VP) was to get a comprehensive solution that enables an immediate software development. Using this VP the development of software could be started although not enough On-board Unit (OBU) Demonstrator hardware was available for all involved SafeTRIP partners at the beginning. This approach also helped to ensure and increase the understanding and interoperability of software developed for the OBU Demonstrator by different partners.

By defining a consistent set of libraries, API versions and toolchain components, the porting effort caused by varying development platforms (e.g. from a development PC back to the OBU Demonstrator) that frequently arise during the software development, test and preliminary integration phase has been minimized or even avoided completely. A further advantage is that by providing a set of test-suites via the Virtual Prototype well in advance, the development and the debugging of applications and services were considerably improved.

Software Distribution

Software Distribution in this case means the distribution of software components from the developer to the user. In the framework of the SafeTRIP project several partners took the role of the developer. The user's role is mainly associated with the role of the overall system integrator. The idea behind the design of the OBU Demonstrator Virtual Prototype was to address the needs of these two roles. One of the requirements was that the user should be able to automatically (as far as possible) install and upgrade software components – and this without the need to know about details of the installation and upgrade procedure. However, the developer requires detailed information about the target system and how to install software components. In the best case, the information where the software will be installed is sufficient. From the user's perspective a software database and an automated installation of selected software should be provided. The OBU Demonstrator base system has its origin in a Debian Linux Distribution. In order to meet the predefined requirements, the decision was made to use Debian Package Management System for the SafeTRIP software distribution and particularly for their final integration. This meant that all software components developed for the OBU Demonstrator had to be available as Debian binary packages. Additional, it provides an easy way to express the dependencies to other packages that need to be installed for proper operation. Summarized, this kind of package distribution benefited significantly by the definition of the Virtual Prototype and offers furthermore an easy way to install new software versions or to upgrade existing ones.

SOAP based APIs

In the SafeTRIP project, several hardware and software components had to be developed by different project partners. In order to support interaction between the different components, there was a need to have a formal description of the software interfaces that would allow parallel implementation and testing to happen. The SOAP[1] protocol and WSDL[2] files for the formal description of these kinds of interfaces were used. SOAP is commonly used for interfacing with web services on the internet. The main advantage of adopting this standard protocol was the abundance of tools that facilitated the development and testing of the interfaces that were implemented.

Common Logging Mechanism

The idea of the Common Logging Mechanism (CLM) was to offer the partners a single service with an easy-to-use data interface for centralized recording of arbitrary logging information. Like the popular Linux syslog service the CLM can accept and process logging messages from any application. Unlike the Linux syslog, the data was saved in binary format instead of simple text. The applications were differentiated on the basis of an ID tag that accompanied each logging message. In addition, the CLM continuously stored the location information (e.g. GPS) and the overall system status information so that all recorded data/messages are always correlated with position and time information. Given that the disk space available on the OBU was limited, the logging data had to be compressed. This was also done by the CLM. For increased usability of the system, the CLM was designed so that it was possible to automatically copy the logs from the OBU disk to a memory stick. This would allow logs to be collected with ease during the trials subsequently. This had two main advantages – firstly, it would allow the unloading of the OBU disk, and secondly, in the event that there was a disk failure during the trials, not all data would be lost, if they were downloaded through the memory stick on a regular basis. The data on the memory stick was then to be uploaded to a centralised server for post-processing. The post-processing output is then used to populate multiple databases and making the logged data available for detailed analysis.

The integration phase: from concept to reality

During this phase, both the hardware components and software modules had to be integrated and validated. What made this task even more challenging was the heterogeneous nature of the components and modules. For instance, while some parts were automotive compliant, others were derived from laboratory equipment (industrial PC, power supply, etc.). In order to ease the SafeTRIP platform integration and to prevent multiple issues from arising concurrently, the integration has been carried out systematically by using a step-by-step set of tests. Additional

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1 http://www.w3.org/TR/soap/

2 http://www.w3.org/TR/wsdl.html

features of the architecture were progressively installed and activated to ensure that the system behaved properly at each iteration. Thanks to this approach the risk of unexpected integration problems occurring was minimized.

The first part of the integration phase was carried out in a laboratory at DLR premises near Munich. During this phase, no Radio Frequency (RF) equipment was used and the whole SafeTRIP platform (OBU and Hub) was integrated in a laboratory rack (Figure 2). This allowed the work to focus solely on the integration of the SafeTRIP applications with the middleware [4] and the hardware components of the OBU. It was equally possible to check the correct behaviour of the server components of the platform and certain applications simulated in the laboratory. Thanks to the good communication among partners during the development phase and to the use of a common software components format (Debian binary package), no major issues were faced during this part of the integration phase, although automotive and non-automotive modules were integrated together.
The RF-components have been tested also in a controlled environment first, using fading channel simulators. Fraunhofer carried out initial tests of the performance of the satellite link before integration with the application software. A full test was postponed to the tests after the next part of the integration work.

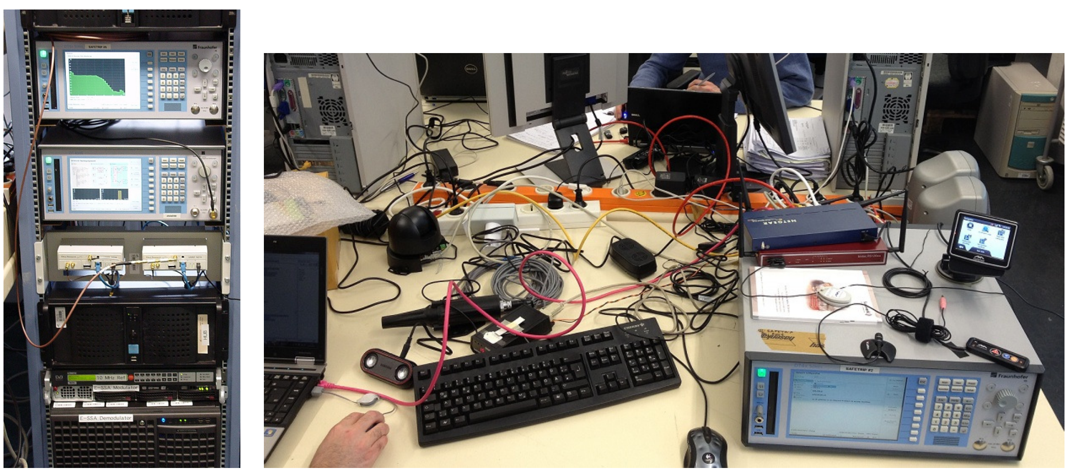


Figure 2: SafeTRIP platform during integration phase in the laboratory

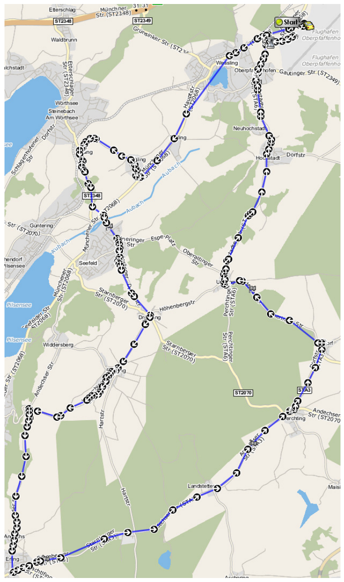
In the second part of the integration phase, the system was tested in an uncontrolled environment including the real satellite radio link. The OBU moved from the lab setting into a test vehicle (Figure 3) so as to carry out field tests with RF components (antennas, satellite, hub) and monitor the behaviour of the applications when used under real conditions. The goal of these preliminary field tests was to detect potential problems when moving out of the controlled lab-environment well ahead the start of the official field trials. Focusing on the applications, the driver HMI mounted (Figure 3 (b)) on the dashboard provided access to the navigation application and all driver related SafeTRIP services (Road Safety Alert, Collaborative Road Alert and Stolen Vehicle Tracking). The passenger services (Multimedia, Live TV and Info Explorer) could be accessed through a 10 inches Tablet PC which was connected to the OBU through WiFi. The Emergency Call Service designed to be used by both driver and passengers could be triggered using a 3-button interface. Furthermore a monitoring system (available via the Tablet PC) has been implemented so as to ensure the driver of the correct functioning of the OBU.

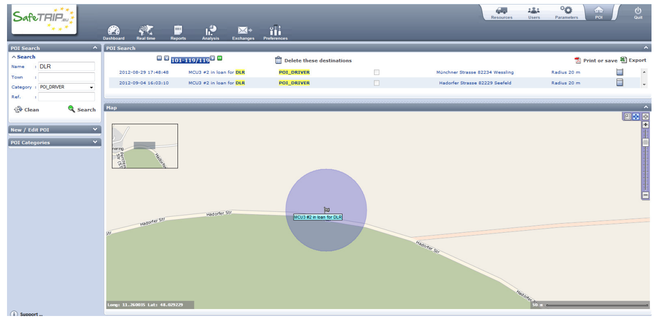
The most challenging part of this integration phase was to correctly tune all the different parameters that impact the data transmission and reception over the satellite link. As the antenna, the hardware and the software came from different partners, some difficulties were encountered during the first field tests to retrieve the emitted data from the vehicle at the server side. After some deep and thorough investigations of the transmission settings facilitated by the use of the CLM, parameters could be better tuned so to obtain a stable satellite communication link for the field trials.

(a) (b) (c)

Figure 3: DLR Test vehicle (a), the driver HMI (b) and the rack containing the OBU (c)

Intensive tests were then carried out with the test vehicle around DLR premises to monitor the behaviour of applications when subjected to fluctuation in satellite coverage and reception – typically found under real world conditions. Figure 4 (a) shows the trail displayed on the server side of the fleet management applications – illustrating the route used by the DLR test van during a typical test session. During this session, a Collaborative Road Alert was emitted by the DLR test van to simulate an accident and was correctly received on the server side (Figure 4 (b)). Furthermore the Road Safety Alert application was equally tested – and successfully displays an alert on the driver HMI (Figure 4(c)).





(b)

(a) (c)

Figure 4: Test Vehicle Tracking (a), Collaborative Road Alert (b) and Road Safety Alert (c)

Finally Figure 5 illustrates the different infotainment services available for the passengers. The latter can access the services using a Tablet PC connected to the OBU through Wi-Fi. The applications that are available include Live TV, weather forecast and Info Explorer [2] which displays the main POIs around the vehicle's position. All these services were rigorously tested during the integration phase.

Figure 5: Infotainment applications available on the Tablet PC

From Lab to Field Trial

Having successfully tested the SafeTRIP system in lab and in the DLR van, the next challenge was to test and validate the system on regular trial vehicles. 4 vehicles were equipped with a complete and identical configuration, 2 cars for use on the French motorways and 2 vans for Spanish motorways. In spite of the fact that key measures were taken during the development phase to ease integration, and the tests during the integration phase were encouraging, the transition to regular vehicle opened up a number of previously unidentified and unresolved issues with both the system and the applications. In particular, the system behaved differently in different vehicles. This is not atypical of large and complex integrated systems.

A particular challenge that had to be met was the geographical dispersion of technical partners and test sites across Europe. The preliminary tests were carried out at trial sites in Paris and Barcelona. During the tests, the tester was able to reach technical partners in France, Germany, Spain and Italy for assistance by phone, and thanks to the remote connection facilities on the OBU, support could be provided remotely by connecting to the OBUs through cellular network. The logging mechanisms and the modular approach used in the design of various software components – supported systematic identification of issues and instant resolution in some cases. However, some issues were more complex and had to be deferred for extensive analysis. A reference system put together during the integration phase proved to be very useful in investigating complex issues and resolving them. Once resolved, software patches were disseminated through the software repository to synchronise all systems.

In spite of necessary steps taken during all previous phases to ensure the smooth transition to the trials, the preliminary tests carried out during the pre-trial phase revealed that there was a much bigger gap than anticipated between the operation of the integrated demonstrator (prototype) in a lab or tests and its behaviour in the wild.

For instance, while the antenna was designed for perfect integration and safe installation by taking a shark antenna form-factor to replace the typical FM radio/GPS/GSM antenna, its operation in real world conditions were sub-optimal and generated results that were different from the tests carried our during the integration phase. As it turned out, the antenna worked well for satellite signal reception, but not for transmission; therefore, an additional antenna had to be installed to handle the transmission.

Perhaps more importantly from the trial perspective, were the issues related to practical aspects of allowing real end users interact with the system and the applications. The first hurdle was the size of the system itself. The use of an industrial PC has been necessary in the context of the SafeTRIP project as the focus had been on flexible hardware configuration rather than miniaturisation. While perfectly understandable from a technical perspective, this is likely to hinder user acceptance of the system. Furthermore, the system required the provision of an additional battery to avoid draining the vehicle's battery – contributing to the inflated size of the system and filling almost the entire trunk of one of the trial vehicles (Figure 6).

Figure 6: The OBU and power supply in the vehicle's trunk

Another issue was related to the type of service provided by telecom operators across Europe. A UMTS connection was included in the SafeTRIP platform to act as an alternative communication link to the satellite link. In areas with UMTS coverage the capacity can be increased or additional redundancy is provided by the terrestrial link complementary to the satellite link. Using UMTS added additional challenges, as it happened, the service provided by the different telecom operators is not fully homogenous in the European context; for example, the VOIP (Voice over IP) for emergency call is not supported by all European operators.

In the integration phase, the focus of the tests had been on the correct operation of the system and application, with preliminary tests conducted without real end-users. A challenge for the pre-trial preparation phase was to give due consideration for the usage of the equipment and application in the wild. Regular users were unlikely to treat the system with the same care as testers and developers, typically using the applications and features in a random fashion. For instance, a specific powering procedure was required to start the system. This procedure, if not followed, would lead to unexpected behaviour. Thus, training material had to be prepared for end-users – both for using the system and the applications.

Conclusion

In large and complex projects such as SafeTRIP, an integrated and easy-to-use Package Management System is a good technique for a fast and efficient software distribution and installation process – at all stages of the project from development through to trial phase where the uniform dissemination of fixes is desirable to maintain consistency between multiple instances of the system on OBUs. It is also clear that such a software distribution system will not cover all issued coming up during the hardware integration. An additional *field integration phase* would be beneficial in large integration projects that aim to undertake trials with real users. This would allow sufficient time and effort to be spent on fine tuning the system.

A reference system is essential for debugging activities throughout the development, integration and trial phases. This reference system has proven to be very useful for SafeTRIP as it has enabled detailed tests and analysis to be conducted using appropriate tools to reproduce certain system behaviours on the field and to troubleshoot reported issues. On the field, it is very difficult – if not impossible to conduct such detailed troubleshooting without the adequate tools. This reference system will be maintained throughout the SafeTRIP trial. It is also recommended to have an adequate number of spare systems and units. During the pre-trial tests, as expected, some systems have suffered from hardware malfunctions, and thanks to the foresight of the consortium, prompt substitution could be provided in order to pursue further testing.

Unlike many R&D projects, which conclude with orchestrated tests, SafeTRIP aims to deploy and test the system with real end-users – a feat seldom performed within projects of such complexity. The consortium was aware on the challenge of such tests, nevertheless we underestimated the effort necessary to bring a system from the laboratory to "end-users". While initial test results do show a number of issues that need to be addressed, the road to trial is already paved and the upcoming trials will provide interesting results as well as lessons for future large integrated ITS projects dealing with complex technologies.

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