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A-to-Be experience: deploying a Portuguese highway C-ITS network under C-ROADS Portugal

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Abstract

Over the last few years, A-to-Be, powered by Brisa, has been developing state-of-the art mobility solutions, including an end-to-end C-ITS framework that addresses interoperability among different road operators and across borders. This article describes A-to-Be's vision, approaches and main roles for the Portuguese C-ROADS project, which started in November 2017 and will last for 4 years. It consists on a large-scale deployment divided on 5 macro pilots that cover urban, rural and cross-border areas, aiming for the validation of harmonized and interoperable cooperative systems in Portuguese infrastructures.

Keywords:

C-ITS Deployment, C-ROADS, ITG-G5

Introduction

Cooperative Intelligent Transport Systems (C-ITS) have been fast-evolving to provide innovative services for increasing safety and reducing the environmental impacts of transport.

These systems, specifically those that use Dedicated Short-Range Communications (DSRC) for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, assist drivers by warning about road occurrences beforehand, contributing for accident and traffic congestion reduction.

Although, for these systems to work effectively, a harmonized set of standards between the C-ITS infrastructure and vehicle equipment are needed [9]. Lately, great efforts have been made to develop harmonized standards for cooperative vehicles. By increasing the interoperability across manufactures such standards will accelerate C-ITS deployment.

C-ROADS is a great example of one joint initiative of European member states for testing and implementing C-ITS services considering cross-border harmonization and interoperability [1].

The Portuguese national pilot, *C-ROADS Portugal*, which started in November 2017, has a duration of 4 years and is co-financed by the European Connecting Europe Facility Program. It aims to develop, harmonize and deploy C-ITS systems at scale in Portugal. It counts with 31 national partners aligned with the same ambition of making Portuguese roads safer, promote a more sustainable mobility and reduce greenhouse gas emissions from road transport.

A-to-Be (the Brisa Group company dedicated to the development of technological solutions) is the project partner, responsible for defining and coordinating the technical and functional specifications of the systems that constitute the C-ROADS architecture and demonstrate the services in the National motorway network.

The following couple of sections provide a brief overview of the project and European platform where it is inserted. A detailed description of one pilot is provided, elaborating on the C-ITS services, specifying the use cases and requirements. Finally, conclusions are drawn.

C-ROADS Platform

The C-Roads Platform started in 2016 with the joint cooperation of 8 European Union member states and currently has 17 (Austria, Belgium / Flanders, Belgium / Wallonia, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, the Netherlands, Norway, **Portugal**, Slovenia, Spain, Sweden, and the United Kingdom). Its main objective is to link the different activities of Cooperative Intelligent Transport Systems (C-ITS), promoting knowledge share among the various partners for a harmonized and interoperable large-scale implementation across Europe.

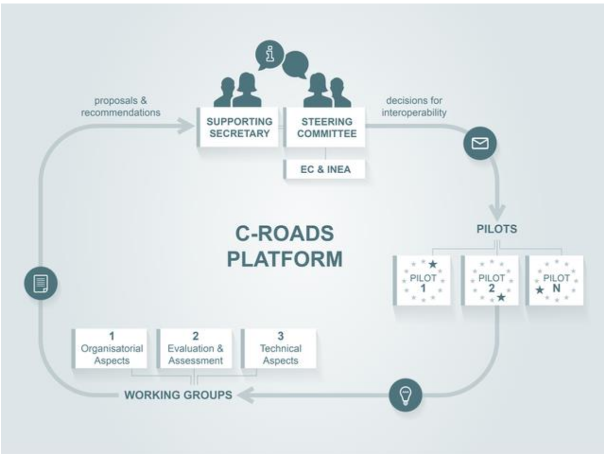


Figure 1 – C-Roads Platform communication and organizational structure [1]

National C-Roads projects take a more practical approach with the implementation of multiple internal and cross-border pilots involving different road operators, public entities and service providers to validate different implementations.

This bottom-up approach allows evolution in parallel at distinct paces, sharing and unifying the results of experiments through the platform that serves as an aggregator and unifying point of technology. To achieve these goals and facilitate the communication and decision-making process of the various themes, Figure 1, three working groups were defined (organizational aspects, technical aspects and evaluation & assessment).

Project C-Roads Portugal

The national initiative started in November 2017 for a period of 4 years, is co-funded by the European Connecting Europe Facility Program and involves 31 national partners. It's coordinated by the Institute for Mobility and Transport (IMT), and is committed to make Portuguese roads safer, promote more sustainable mobility and reduce greenhouse gas emissions through more efficient use of the infrastructure. Through the implementation of 5 macro pilots (Figure 2) it aims to develop, harmonize and deploy C-ITS services along the Atlantic Corridor, covering the core and comprehensive network by approximately 1000 kilometres of infrastructure with an envisioned 180 roadside ITS stations (R-ITS-S) and 162 vehicles in operation [2].

These pilots foresee several experimental sub activities in a phased manner to reach the following objectives:

- Increase the safety of priority vehicles, autonomous vehicles and traffic in tunnels;
- Improve the quality of service provided by displaying information near drivers, using mobile applications and interfaces within vehicles that receive and send information using the implemented C-ITS network;
- Reduce congestion and pollutant emissions by providing users with predictive travel time and route advice tools, powered by real-time monitoring data;

Develop mobility data sharing tools, creating central access points and standard interfaces that can be used throughout the community.

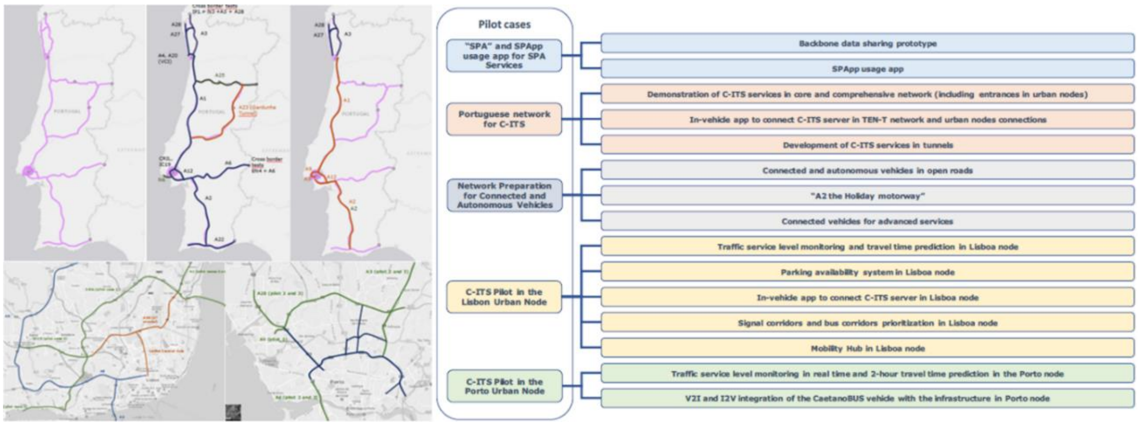


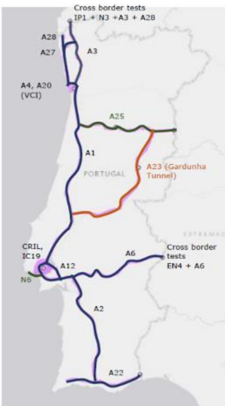
Figure 2 – 5 macro testbed pilots envisioned in C-Roads Portugal [1]

The project is composed of 31 partners, including city councils, public and private motorway concessionaires, universities, technology and consultancy companies.

A-to-Be has the role of coordinating the systems specification process that will be developed and implemented in the project, so the deployed services are based on a common interoperable foundation. Namely, use case and standard analysis; functional and technical specification inserting cellular communications as a long-range alternative to radio vehicle networks (ITS-G5); and development of a common platform for technical evaluation of pilot results. Additionally, it is coordinating the implementation of some activities for the "Portuguese Network for C-ITS" pilot.

“Portuguese network for C-ITS” Pilot

The “Portuguese network for C-ITS” is one of the 5 macro pilots, which plans expanding the existing C-ITS network with the deployment of “Day 1” and “Day 1.5” services over a length of 460 km to cover ITS-G5 in the core (A1, A2, A3, A6 and A12) and comprehensive (A2, A22, A27 and A28) network, including cross-border sections (A3, A28 and A6) and roads giving access to Lisbon (IC17 and IC19) and Porto (A4 and A20) metropolitan areas (Figure 3).
To accomplish this, A-to-Be will install 32 R-ITS-S and use 10 connected vehicles over a final network comprised of 460 kilometres of roads with 115 R-ITS-S and 64 V-ITS-S. In addition, the Portuguese security infrastructure will be put to test to be later integrated with the European one. Finally, to extend service coverage a hybrid communications network will be deployed that uses cellular communications for the long range in conjunction with the vehicular radio communications for the short range and low latency applications.



Covered road infrastructure:

- A1 – 30 km
- A2 – 30 km
- A3 – 40 km
- A4 – 30 km
- A20 (VCI) – 11 km
- IC17 (CRIL) – 19 km
- IC19 – 17 km
- A6 – 20 km
- A12 – 20 km
- A22 – 90 km
- A27 – 25 km
- A28 – 89 km

Summary numbers:

- 460 km
- 54 OBUs
- 115 RSUs

Figure 3 – “Portuguese network for C-ITS” pilot deployemnt numbers

A-to-Be pilot use cases

This section illustrates the use cases A-to-Be will deploy under the scope of this pilot. The rationale behind this use case selection was based on the fact the equipment would be installed on Brisa’s infrastructure that covers just motorways. Meaning that most of the use cases are supported by V2I communications:

1. ***PVD-VDC: Probe Vehicle Data - Vehicle Data Collection***
   Vehicle data is collected anonymously by the road operator or service provider. The main objective is to improve traffic management and trigger other I2V use cases.
2. ***HLN-APR: Hazardous Location Notification - Animal or person on the road***
   The presence of animals on the road is detected and the event broadcasted to the vehicle and consequently the driver through the onboard dashboard.
3. ***HLN-WCW: Hazardous Location Notification - Weather Condition Warning***
   The information about static and dynamic weather conditions are sent to the vehicles. The vehicle drivers can adapt the driving behaviour according to visibility and road conditions.

4. ***HLN-SV: Hazardous Location Notification - Stationary vehicle***
   Approaching drivers are warned about stationary/broken down vehicles ahead.
   The road operator can use information from cameras or broadcasted V2V messages by the stationary vehicle to trigger this event.
5. ***HLN-TJA: Hazardous Location Notification – Traffic Jam Ahead***
   The information about a queue formation on the respective lane or road is sent to drivers approaching the area. Since speeds in motorways are usually high, this use case takes more relevance because drivers can reduce velocity gradually avoiding accidents.
6. ***HLN-EVA: Hazardous Location Notification – Emergency Vehicle Approaching***
   The vehicle drivers are warned about the approaching of an emergency vehicle, which broadcasts its real-time position. This use case can increase emergency response and reduce the number of accidents with emergency units.
7. ***HLN- AZ: Hazardous Location Notification – Accident Zone***
   The road operator detects that an accident has happened on the network and broadcasts the information to road users that can benefit from this information. Like on the stationary vehicle use case, the road operator can take profit from the infrastructure sensors to trigger this event.
8. ***RWW-LC: Road Works Warning - Lane closure***
   The road user is informed, due to road works on site, about the closure of part of a lane, whole lane or several lanes (including hard shoulder), but without the complete road closure.
9. ***IVS-DSLI: In Vehicle Signage – Dynamic Speed Limit Information***
   The road users receive speed limit notifications as they drive. These display onboard dynamic speed limits set by the road operator, currently transmitted to the variable message signs (VMS).
10. ***IVS-EVFT: IVS - Embedded VMS "Free Text"***
    The road users receive in their car reproductions of the "free text" shown on physical VMS or whole new messages for locations without a physical VMS.
    Additionally, the messages can also be translated in the preferred language to provide a more comprehensible information for foreign users.

Figure 4 exemplifies a case where an accident occurs. The road operator's infrastructure is warned through reported vehicle data or is manually triggered by the road user through an in-vehicle HMI. The operator's traffic management system validates incoming events and triggers two use cases (IVS-EVFT and HLN-AZ) to effectively warn upcoming traffic.

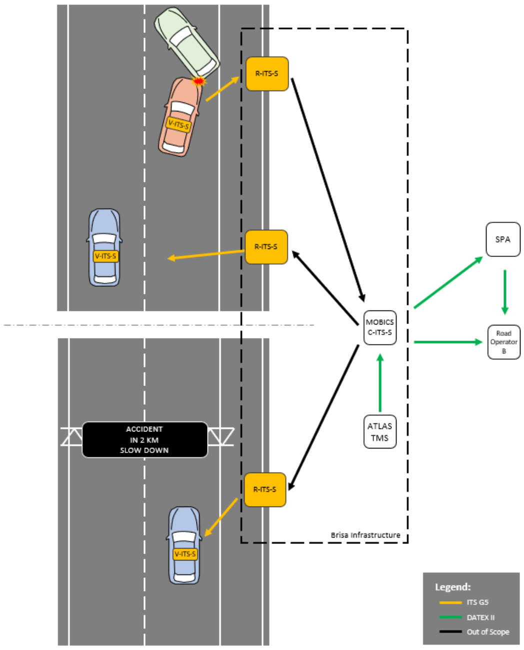


Figure 4 – Example combining two use cases IVS-EVFT and HLN-AZ

The specification for these use cases was done by aligning the Portuguese implementing bodies perspective and work made on the platform [7].

A-to-Be's C-ITS architecture

To implement the former, A-to-Be brings the C-ITS architecture [8] depicted in Figure 5. It is composed by 5 layers to connect the back-end software systems and the connected and cooperative vehicles. Furthermore, the developed operator infrastructure communicates with the national services brought by other project partners (security and national access point) and additional road operators through defined interfaces.

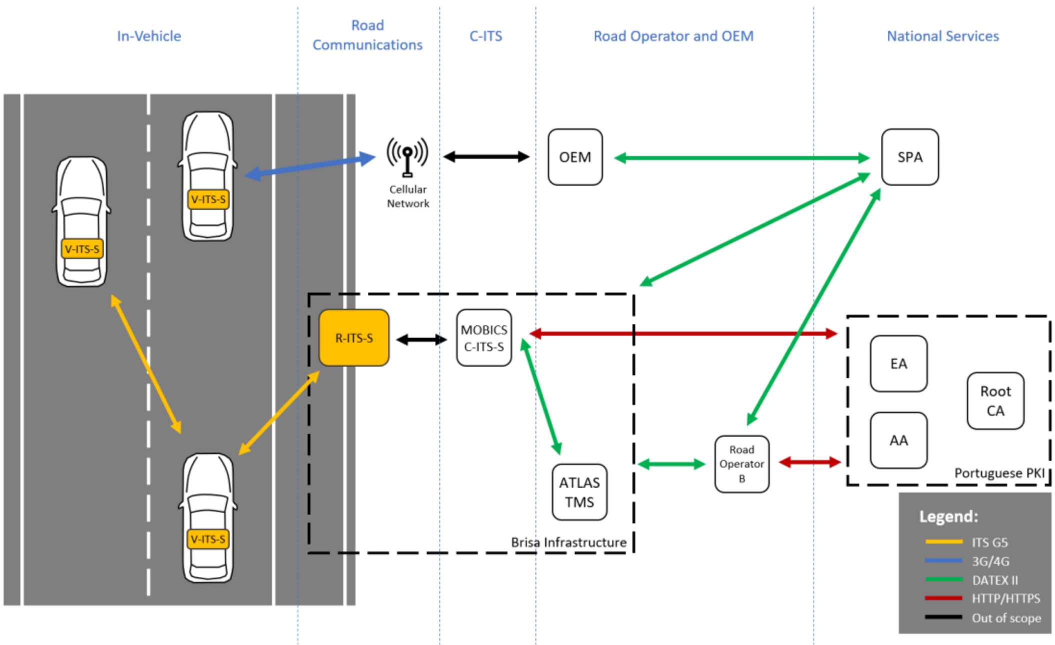


Figure 5 – A-to-Be's C-ITS architecture

National Services Layer

The National Services layer encompasses all nation-wide services necessary for this project. It is made-up of the DATEX II Single Point of Access (SPA) and the C-ITS public key infrastructure (PKI). The SPA communicates with Road Operators and OEM. The PKI is a mandatory element for guarantying security of C-ITS systems through certificate delivery/revocation.

Road Operator and OEM Layer

This layer includes the operational platforms for different entities, in the case of Portugal these entities encompass Road Operators and OEM. In the case of Road Operators, their Traffic Management Systems (TMS) are integrated with the SPA and internally with the C-ITS-S using DATEX II. Although there are currently no specific OEM partners in this Pilot, the architecture and options taken allow for the easy addition of OEM entities to the solution.

C-ITS Layer

It abstracts the communication with different traffic management systems by using DATEX II as communication protocol between TMS and the C-ITS Station (C-ITS-S), since most TMS already use DATEX II for exchanging messages.

The communication between C-ITS-S and R-ITS-S is made using C-ITS messages (CAM, DENM and IVIM) but the communication technology underneath can vary accordingly to the networks of different Road Operators, namely between fibre and 3G/4G LTE communications.

Furthermore, the C-ITS-S is responsible for abstracting the R-ITS-S from the network. Whenever a TMS triggers a use case for the C-ITS-S, it decides on which stations must be selected to broadcast the appropriate messages.

Road Communication Layer

This layer is responsible for doing the interface between central back-end system and vehicles. The roadside equipment exchanges information with vehicles using the standardized ITS-G5 protocol. This communication is also known as I2V.

It is on this layer where a big part of the project effort resides, as it aims for inter-sub-system interoperability between infrastructure and vehicles.

In-Vehicle Layer

The In-vehicle is the layer of the end users, this layer includes an application that will act as a dashboard of the vehicles, where the drivers can be warned about any incident sent by the road operators.

The application will work as a navigation application where the driver can see his position and be warned in real time about incidents on the road, as well as other type of information like nearby parks or traffic information.

Hardware description

Since the available Commercially Off-The Shelf products have black box implementations of the IEEE

802.11p standard and the technology is evolving at a fast pace, our company challenged a team from Institute of Telecommunications (IT) at Aveiro University to work on the amendment and to design a protype system [4]. Setting as main requirements being able of operating both as a road-side and on-board unit and be flexible to adapt for future standard modifications.

ITS stations configured as roadside stations have been designed to be installed inside cabinets (like the one on Figure 6) along the highway. When configured as V-ITS-S they are powered through the vehicle battery, using a 12V DC lighter plug.

Figure 6 – Example of a Brisa's roadside equipment

Figure 7 has an exploded view of A-to-Be's ITS-G5 station developed that contains the following components:

- Single Board Computer (SBC) that runs a Linux operating system distribution, responsible for executing some layers of the protocol stack, log communication messages and to flexibly update the full system;
- GPS module for providing the position data and clock synchronization, required by the 802.11p standard [3];
- Radio board (Figure 8) designed in-house that contains an FPGA, 2 radio frequency modules due to multi-channel operation standard requirement and an interface for the GPS module. This component converts and amplifies signals for the radio channel and implements the low level physical and MAC layers.

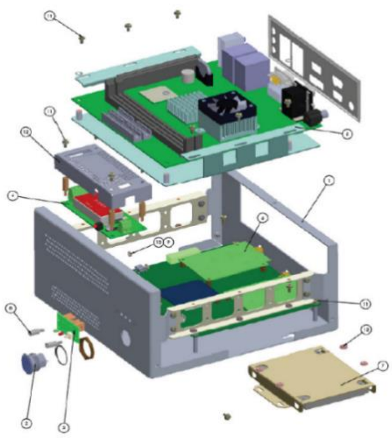


Figure 7 – A-to-Be ITS station hardware

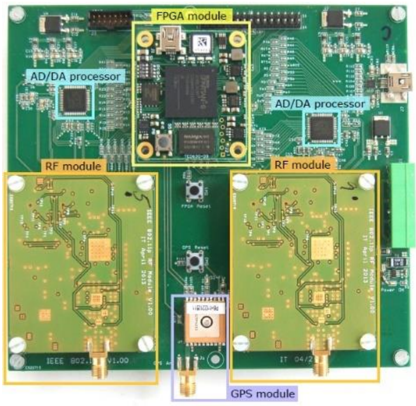


Figure 8 – Radio and interfaces board [4]

Onboard graphical user interface

The onboard unit connects to an Android application that runs on a standard phone or tablet. It gives the user an intuitive and pleasant interface for reporting a big variety of common warnings and informs about active events on the road. These events are mostly originated in the traffic management system. The following Figure presents an example running in real conditions.

Figure 9 – A-to-Be's C-ITS human machine interface

This solution is being upgraded to implement the use cases a above mentioned and provide a more intuitive tool that presents the information over a map working in a way similar to a navigation application.

Central C-ITS system

An efficient C-ITS infrastructure management involves interfacing and successfully sharing information with several heterogeneous hardware and software modules. Moreover, A-to-Be has an innovative solution implemented for traffic management called ATLAS responsible for managing road traffic infrastructure and process road incidents. Under project SCOOP@F part 2 [10], a new platform MOBICS (Mobility Intelligent Cooperative Systems) was built for managing the data exchange between C-ITS devices, existing road infrastructure and traffic management solutions.

It adopted an open architecture [5] that makes possible the cooperation with multiple central systems aiming for the removal of human intervention. This way, for example, the traffic management operator

only sets the events on specific locations in the TMS (like he already does) and the system automatically routes the events to specific R-ITS-Ss.
To monitor or debug individual systems, a pleasant web interface was created, capable of checking R-ITS-S status, setting rules for specific events, build/send standard messages by selecting a given R-ITS-S and filter out received events or awareness messages.
An example of the Dashboard page can be seen on the following image:

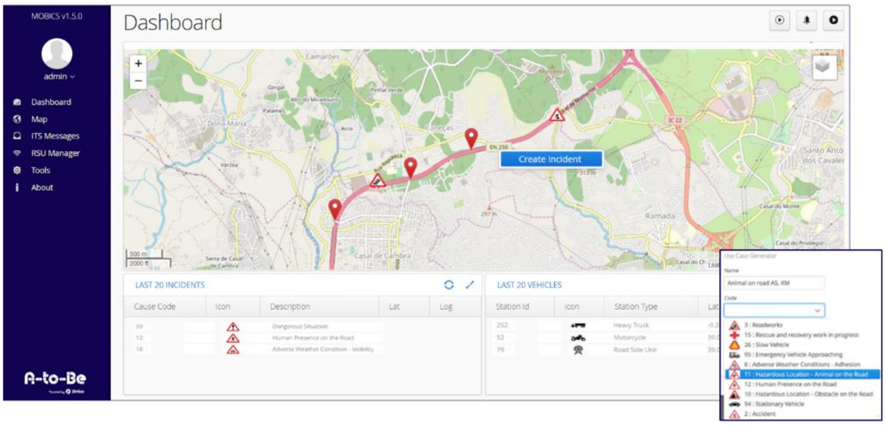


Figure 10 – MOBICS dashboard view with events and R-ITS-S locations

Conclusion

Envisioning harmonized and interoperable C-ITS network means involving all the stakeholders to agree on the systems specification. It is crucial to involve private and public road operators, transport authorities and decision-makers since day one.
We started by conducting several surveys to assess the implemented standards and versions, discussing in detail the differences and come up with an implementation plan for a minimum common set that fulfils the project objectives. This set came from the design of specific use cases and according with the requirements obtained from this study. After that, we planned cross validation trials where each implementing partner opens its infrastructure to the other partners to evaluate deployed systems.
Agreeing in every single topic throughout these phases can be time consuming, as public and private entities have different and valid viewpoints.
However, this work was not done only at national level but in cooperation with other member states by attending and synchronizing the work done under the C-Roads platform with the workgroups leveraging from the good and bad experiences from other countries.
Even with all the delays, C-ROADS Portugal consortium will have around 1000kms of road infrastructure covered by the end of this year.
This technology will contribute for the adoption of a more preventive driving by warning about dangerous situations beforehand. In addition, will increase traffic monitoring maturity leading to a more efficient and environment-friendly road transport network. Nevertheless, it is of extreme importance to come up with policy guidelines and business cases for the large-scale deployment of these services.

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