Paper ID # 376

# Deployment and Interoperability tests for a Portuguese network for C-ITS

**Jorge Pais Ribeiro[1], Tiago Delgado Dias[2], Lara Trigueiro Moura[3]**

1. jorge.ribeiro@a-to-be.com, A-to-Be, Portugal
2. tiago.delgado.dias@a-to-be.com, A-to-Be, Portugal
3. lara.moura@a-to-be.com, A-to-Be, Portugal

**Abstract**

Over the last few years, A-to-Be, powered by Brisa, has been developing state-of-the-art mobility solutions. One such solution is an end-to-end C-ITS framework that addresses interoperability among different road operators and across borders. This report describes the architecture and solutions A-to-Be deployed in Brisa's road network under the C-Roads Portugal project, co-financed by the European Commission for the development and implementation of interoperable C-ITS services.

**Keywords:** C-Roads, C-ITS Deployment, V2X, ITS-G5

## Introduction

We live in a connected world, where every device is linked to several others. Cooperative Intelligent Transport Systems (C-ITS) are thus a natural path of technical evolution, providing services to road users and allowing the exchange of information between them and road infrastructures in real-time. This cooperation ensures a coordinated and optimized use of physical resources and actions for increased road safety and efficiency.

Moreover, autonomous vehicles will benefit most from this constant communication, as, without it, their view is limited to the onboard sensors lacking the information gathered from the surrounding devices.

These systems rely on the use of Dedicated Short-Range Communications (DSRC) for direct communication between vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I). Example usages are the announcement of abrupt braking in the vehicle ahead, upcoming road closures or the formation of traffic jams in a highway.

Although there were several efforts and investments made in this field, the deployment of mature and harmonized systems is not yet well established. Mainly due to the adoption of different specifications and the not so obvious business opportunities associated with safety.

After financing multiple initiatives in this domain, in 2016, the European Commission and several Member States launched the C-Roads Platform to link C-ITS deployment initiatives and jointly develop technical specifications and verify deployment interoperability through cross-site testing [6].

C-Roads Portugal is one of the 17 initiatives co-financed by the Commission currently running across Europe. It counts with the participation of 31 partners aligned with the same ambition of making Portuguese roads safer, promoting sustainable mobility and reducing greenhouse gas emissions.

A-to-Be has been working in the software and hardware development for the deployment of C-ITS services for some years now. Partnering with other implementing bodies, A-to-Be was responsible for defining and coordinating the technical and functional specifications of the systems that constitute the Portuguese pilot and demonstrate C-ITS services in the National motorway network.
This paper will briefly describe the project and in more detail the pilot for the implementation of a fully national C-ITS network. Finally, we will go through the actual solutions and architecture A-to-Be implemented in Brisa's road network.

**Project description**

Project "*C-Roads Portugal*" started in November 2017 with co-funding from the European Connecting Europe Facility Program. 31 national partners are working together: city councils, public and private motorway road operators, universities, technology and consultancy companies. It aims to promote the deployment of C-ITS equipment and services across the Portuguese road network (approximately 1000 kilometres) to achieve 4 main objectives [1]:

- 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;
- Reduce congestion and pollutant emissions by providing users with predictive travel times and route advice in real-time;
- Implement mobility data-sharing tools that can be used throughout the community.

To achieve these, the work was broken down into 5 macro pilots (Figure 1):

1. *Single Acess Point – SPA and SPApp usage app for SPA Services* – Implementation of a national access point in compliance with the Commission Delegated Regulation (EU) 962/2015 and 886/2013 and a mobile application that will provide added value services on top of the information gathered by the access point;
2. *Portuguese network for C-ITS* – Deploy and test C-ITS services across the core and comprehensive network covering over 460 km of road infrastructure;
3. *Network preparation for Connected and Autonomous Vehicles* – Deploy and prepare TEN-T network for Connected and Autonomous Vehicles with second and third level of automation;
4. *C-ITS pilot in Lisbon's urban node* - Implement C-ITS services related to an urban node. Measurement of traffic volume at vehicle entrances/exits, assistance to users in finding vacant parking spaces and routing to charging stations for electric vehicles are some of the services offered;
5. *C-ITS pilot in the urban node of Porto* - monitor and estimate for a 2-hour horizon, the traffic status over a 24 km extension within the city and an integration of a "smart bus" that will exchange information with the infrastructure to be presented to users through a variable message sign.

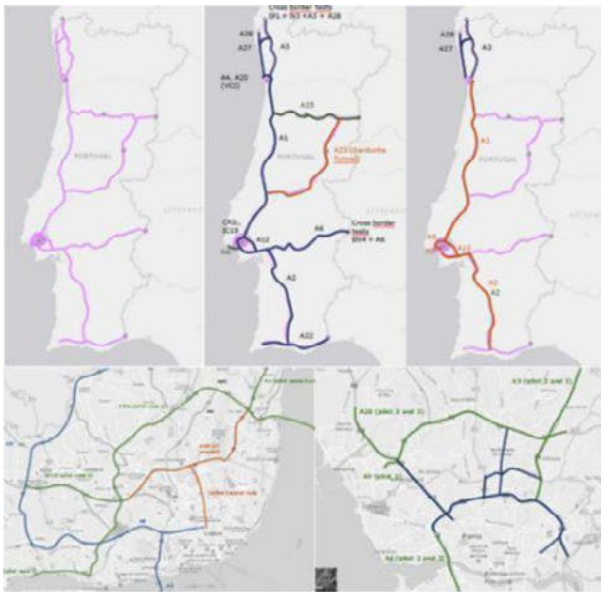

**Figure 1 – 5 macro testbed pilots making up C-Roads Portugal [2]**

In the first stage, each implementing body needed to contribute to the systems specification process, which was lead by A-to-Be, so the deployed services were based on a common interoperable foundation closely harmonized with the outputs from the C-Roads Platform. Namely, use case and standard analysis; functional and technical specification; and development of a common platform for technical evaluation of pilot results.

**A-to-Be C-ITS Infrastructure deployment**

Under the second macro pilot "*Portuguese network for C-ITS*" A-to-Be and BCR[1] partnered with SCUTVIAS, GMV, Norte Litoral and Infraestruturas de Portugal to expand the existing C-ITS network and deploy several C-ITS services over a length of 460 km to cover with ITS-G5 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 2 depicts the planned infrastructure, covered range, and A-to-Be's selected locations for the 32 roadside ITS stations (R-ITS-S) from a total of 115 units to be deployed by all pilot partners. This equipment is being deployed in batches during different project phases.

[1] Brisa Concessão Rodoviária (Road Operator)

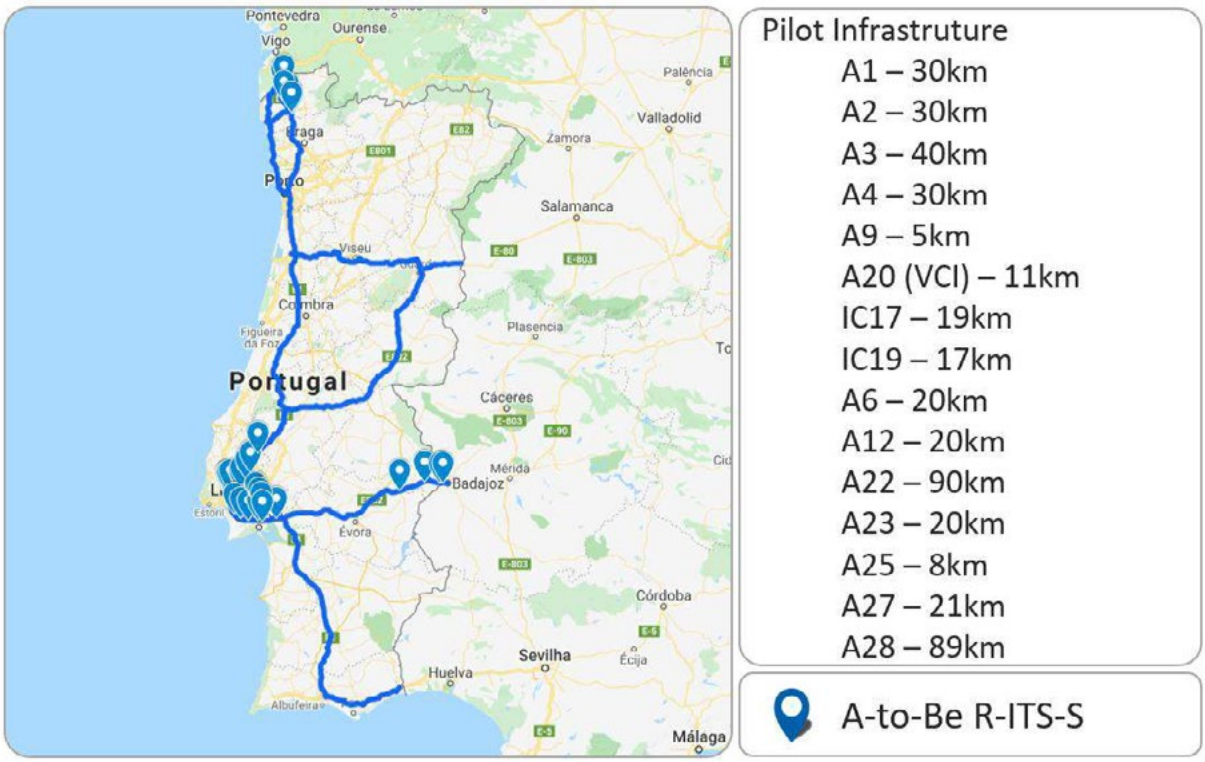


**Figure 2 – A-to-Be's R-ITS-S deployment locations**

For this, A-to-Be implemented an end-to-end solution covering every component of the C-ITS system, graphically presented in Figure 3. It is composed by A-to-Be V2X stations that can either go on-board the vehicles (V-ITS-S) or inside roadside cabinets (R-ITS-S) communicating using ITS-G5 radio or 4G cellular. Then, communication between the roadside equipment and the traffic management system (A-to-Be Atlas) is done using an intermediary node called A-to-Be MOBICS which acts as the central ITS station (C-ITS-S). This C-ITS infrastructure also communicates with national services brought by other project partners, namely the National PKI for security and the National Access Point (NAP) for data exchange.


**Figure 3 – A-to-Be's V2X Solution**

*A-to-Be V2X Station*

This C-ITS station has been developed over several years [3][5] to avoid black box implementations of ETSI standards and provide flexibility to adapt for future standard modifications. It can be configured as a roadside unit (Figure 4) as it was designed to be installed inside cabinets along the highway, accommodating both cellular and ethernet interfaces to connect to the C-ITS-S.


**Figure 4 – A-to-Be's R-ITS-S solution**

Or it can be configured as a V-ITS-S (Figure 5), powered through the vehicle battery using 12V DC lighter plug power and communicating with a user interface installed on a phone/tablet running A-to-Be V2X App.


**Figure 5 – A-to-Be V-ITS-S solution**

*A-to-Be V2X App*

The application gives the user an intuitive and pleasant interface for reporting a big variety of common warnings and informs about active events on the road placed by the Traffic Management System or reported by other road users, Figure 6.


**Figure 6 – A-to-Be V2X Application**

*A-to-Be MOBICS*

An efficient C-ITS infrastructure was developed for successfully managing and interfacing with heterogeneous hardware and software, it's called A-to-Be MOBICS [4]. A-to-Be MOBICS integrates with A-to-Be's ATMS (A-to-Be Atlas) so traffic management operators only need to set the events on specific locations in the ATMS (like it was already done) and the system automatically converts and routes them to the appropriate 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 in the following image:

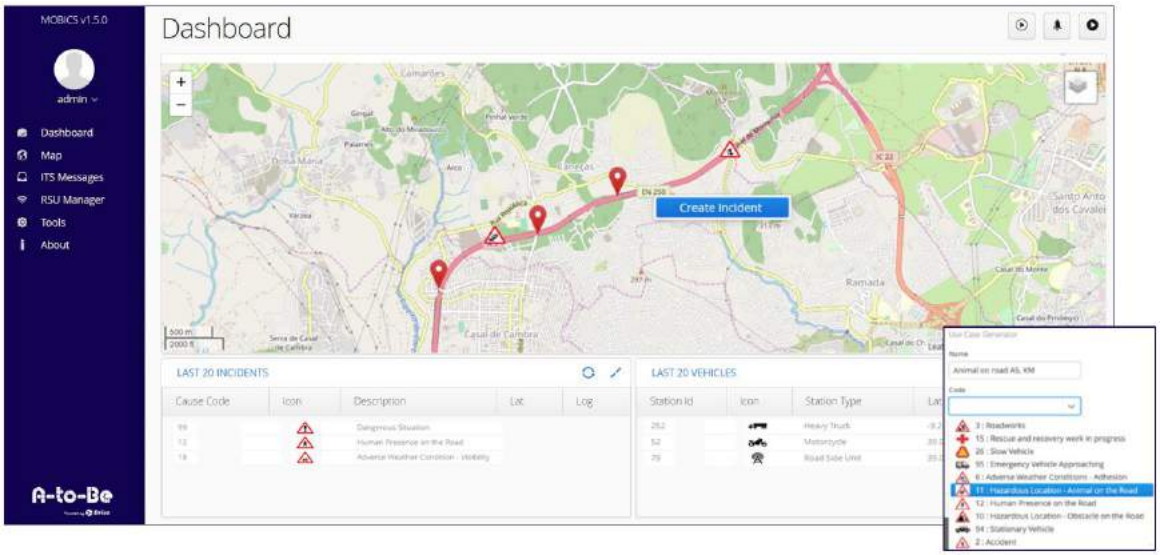


**Figure 7 – A-to-Be MOBICS dashboard view with events and R-ITS-S locations**

It abstracts the communication with different traffic management systems (TMS) by using DATEX II as a communication protocol since most TMSs already use DATEX II for exchanging messages. Hence, it's responsible for generating the correct C-ITS messages and delivering them to the roadside equipment.

**Interoperability tests**

The interoperability among different systems is the key to a successful large-scale deployment. Hence, after cross-checking the technical specifications, extensive practical tests were performed to validate each of the partner implementations of the standards.

*Lisbon tests*

In November 2020, A-to-Be with three different partners Allbesmart/SCUTVIAS, GMV and Infraestruturas de Portugal organized a test event in the Lisbon region, involving 6 connected vehicles (Figure 8), 38 road-side communication units along 77,2 km of infrastructure (A9, IC17, IC19 and

N6).

These tests covered communications between vehicles (V2V), from infrastructure to vehicles (I2V) and from vehicles to infrastructure (V2I) in a wide range of usage scenarios like road weather warnings, road works, accidents and infrastructure information.

**Figure 8 – Connected vehicles involved in Lisbon Interoperability tests**

Each partner placed simulated use cases in their RSUs, materialized as DEN and IVI messages, for validating their reception and presentation in the different systems involved.

A-to-Be selected five common uses cases (Figure 9) and spread them through the A9 highway.


**Figure 9 – Use cases placed by A-to-Be for A9-CREL**

These tests were devoted to assuring that all equipment in vehicles were correctly setup and running, that every participant was visible by all other infrastructures and vehicles and, finally, if all participants were able to receive all C-ITS messages. Although this goal of interoperability was met, there were different interpretations on how to populate and read the standardized message fields (e.g. presence or absence of *traces* in DEN messages or *validFrom* in IVI messages). Due to these differences, some use cases were well received but not correctly shown in all the participants' HMIs. The nature of the tests, with several runs planned from the start, allowed quickly addressing some of the incompatibilities that were found and testing them successfully still during the test event.

A-to-Be successfully received and displayed CA messages throughout the entire span of the tests.

A-to-Be also received 42 distinct C-ITS DEN and IVI messages from the different partners, only failing to receive a single message from GMV. From the 42 messages received only 4 were not shown, 2 IVI messages that didn't have the validFrom and validTo fields and 2 Weather Condition Warning DEN messages. This event also allowed us to confirm the prompt reception and display of C-ITS messages, making the solution perfectly adequate for end-users and real traffic situations.

*Tests in Gardunha Tunnel (A23) and A25 motorway*

In December 2020 Allbesmart/SCUTVIAS and GMV/Ascendi organized test events in the A23 and A25 motorways in the interior of Portugal and near the Spanish border, respectively.

The A23 tests involved 5 connected vehicles and 6 RSU along 23 km of the A23, including the 1.6km Gardunha Tunnel. There were 6 distinct event categories and included events immediately before and after the Gardunha Tunnel. There was a high volume of messages exchanged, more than 200 000 CAM, more than 9 000 DENM and more than 2 000 CAM with tolling protected zones (CAM filled with *protectedCommunicationZonesRSU*).

The A25 event involved the same 5 connected vehicles, 4 RSU along 45 km of the A25 and there was also a high volume of messages exchanged, more than 60 000 CAM and more than 2 000 DENM.

These two test events allowed testing previously untested features like Protected Zones and allowed validating solutions to some other small incompatibilities that were found in the Lisbon trial and during these trials.

**Figure 10 – Connected vehicles involved in A25 Interoperability tests**

A-to-Be successfully received and displayed CA messages throughout the entire span of the tests and lowered emission power in the 2 protected zones announced in the A23. A-to-Be also received and correctly displayed all 10 distinct C-ITS DEN and IVI messages from the different partners.

**Conclusions**

This paper described the C-ITS framework solution developed by A-to-Be and tested with its' partners, working in real conditions. This technology can contribute to the adoption of more preventive driving

through advanced information about dangerous situations, reducing the high number of road accidents. Additionally, the offered possibilities for traffic monitoring by concessionaires will lead to better traffic management, increasing efficiency in the management of resources.

Through the course of 2021, A-to-Be wants to integrate these systems with the Portuguese public key infrastructure to provide signed messages to road users and incorporate new communication technologies (e.g. 5G cellular network) for providing more flexible ways of interacting with the infrastructure.

**Acknowledgements**

The authors would like to thank Institute of Telecommunications (IT) at Aveiro University for their supporting activities in the hardware and software development.

C-Roads Portugal project, with Grant Agreement INEA / CEF / TRAN / M2016 / 1363245, is co-financed by the Connecting Europe Facility Program of the European Commission's Innovation and Networks Executive Agency (INEA).

**References**

1. C-ROADS Portugal Consortium (2017), C-ROADS Portugal Description of Work, C-ROADS Portugal Consortium, Brussels (restricted)
2. C-ROADS Platform (2019), Official C-ROADS Platform website, accessed January 2021, http://www.c-roads.eu/
3. Almeida, J., Ferreira, J., Oliveira, A., (2016). *Development of an ITS-G5 station, from the physical to the MAC layer,* in Intelligent Transportation Systems: From Good Practices to Standards
4. Osório, A., Moura, L., Costa, R., (2018). *The Mobility Intelligent Cooperative Systems (MOBICS): Towards Open Informatics System of Systems. 25th World Congress on ITS*, Copenhagen.
5. Ribeiro, J., Moura, L., Costa, R. (2019), *C-ITS Framework Development and European Test Cases Scenarios, 13th ITS European Congress*, June, Brainport, Netherlands
6. Mobility and Transport, European Commission website, accessed January 2021, https://ec.europa.eu/transport/themes/its/c-its_en