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C-ITS Framework Development and European Test Cases Scenarios

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Abstract

Over the last few years, we have been watching a fast growing in the development of Cooperative Intelligent Transport Systems (C-ITS) aiming for the increase of road safety and environmental impacts reduction. A-to-Be, powered by Brisa has been designing an end-to-end C-ITS framework that addresses interoperability among different road operators and across borders. In this paper, we present the solution achieved and the progress obtained in different test case scenarios, performed under the scope of some European projects.

Keywords:

C-ITS Deployment, DSRC, ITG-G5, back-office

I - Introduction

Brisa is a Portugal-based international transportation company that manages approximately 1600 kilometres of road infrastructure. The company vision is centred on the client, focused on mobility and accessibility solutions following the development of new tendencies, technologies and behaviour changes.

Recently, Brisa adopted a new brand for its technology company - A-to-Be® - that expresses the developments made together with clients, from tolling to parking, from traffic management to monitoring, on what it can be referred as human seamless mobility experiences.

During the last 10 years, A-to-Be has developed several works in the cooperative intelligent transportation systems (C-ITS), namely, the development of an end-to-end framework, that ranges from the radio transmission hardware to the back-office software for managing road infrastructure. This paper will cover the work done in this context by presenting the implemented solution and some of the test cases developed.

Sections II and III of this paper will briefly describe the implemented hardware and software modules that build the C-ITS framework, and Section IV includes the test cases done with the developed technologies under the scope of European projects. Finally, in Section V the concluding remarks are presented.

II C-ITS Equipment

Safety critical applications have hard restrictions on delays and connection times. A couple of seconds would result in car accidents or collisions that sometimes can be fatal. To tackle that Dedicated Short-Range Communications (DSRC) which is a wireless technology working on a dedicated spectrum band at 5.9GHz frequency, was specially designed for vehicular applications requiring real-time operations.

Commonly, a C-ITS infrastructure is composed by the on-board units (OBU) that go inside the vehicle. They communicate with the roadside units (RSU) by using vehicle to infrastructure communications (V2I), or with other vehicles with vehicle to vehicle communications (V2V). RSUs are connected to the road operator infrastructure re-transmitting the information to/from the traffic management centre (TMC). The following Figure depicts this on a graphical manner.

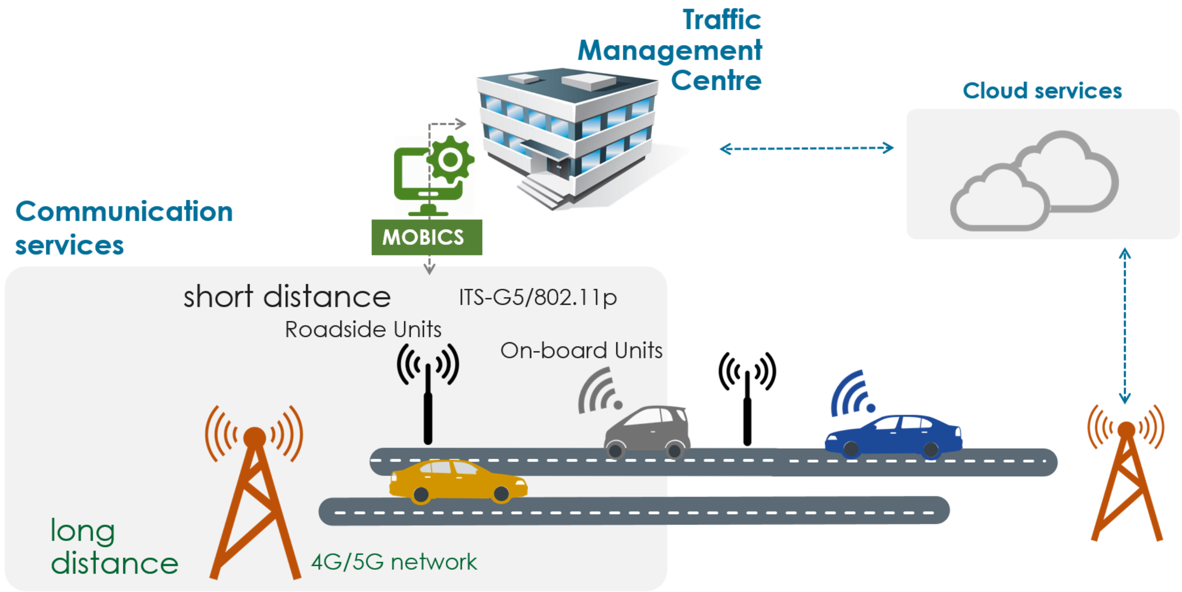

Figure 1 – C-ITS Framework architecture

Hardware Description

Since the available Commercially Off-The Shelf (COTS) chip sets, have black box implementations of the IEEE 802.11p standard, the company challenged a team from Institute of Telecommunications (IT) at Aveiro University to work on the amendment and to design a protype system. The system needed to be capable of operating both as a road-side unit and as an on-board unit, and be flexible to adapt to future standard modifications.

Due to power and wired communications availability, ITS stations configured as RSU have been designed to be installed inside road side cabinets (like the one on Figure 2) along the highway. When configured as OBU they need to be powered through the vehicle battery using 12V DC lighter plug, GPS module for location and synchronization purposes and a human-machine interface for interacting with the driver.

Figure 2 – Brisa's road side cabinets

Figure 3 represents the 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 [2];
- Radio board (Figure 3) that contains an FPGA, 2 radio frequency modules due to multi-channel operation standard requirement and an interface for the GPS module. This board has the main responsibility of converting and amplifying signals for the radio channel, implementing the low level physical and MAC layers

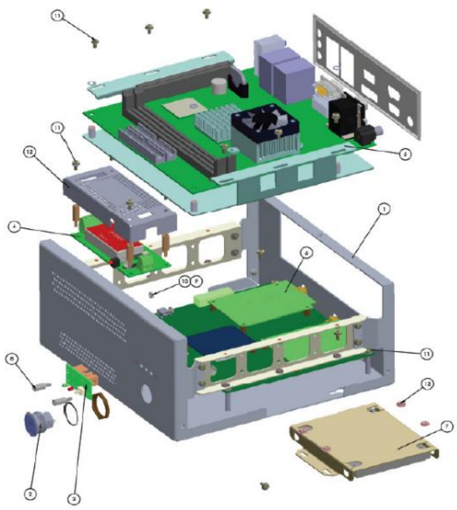

Figure 3 – A-to-Be ITS station hardware components

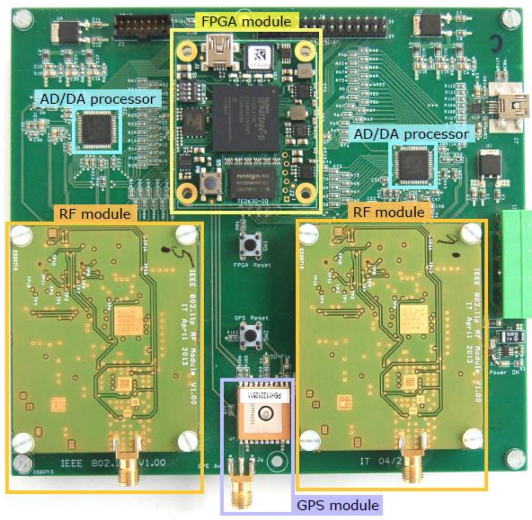

Figure 4 – Radio and interfaces board [3]

Vehicular Communication and Messaging Standards

For the access layer in vehicular communications there are two main standards specifying the protocol stack for supporting vehicular in an ad hoc networks (VANET): IEEE WAVE, used in the US [4] and ETSI ITS-G5 used in Europe [2]. Although, both standards share the physical layer and the medium access control layer specifications covered in IEEE 802.11p amendment [5], the latter also adds features for decentralized congestion control (DCC) and requires the use of service and control channels operating in conjunction.

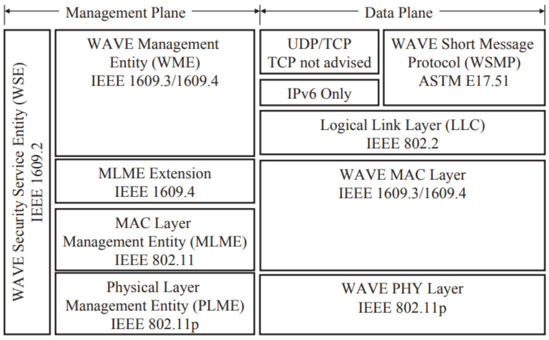

Figure 4 - IEEE WAVE reference architecture [4]

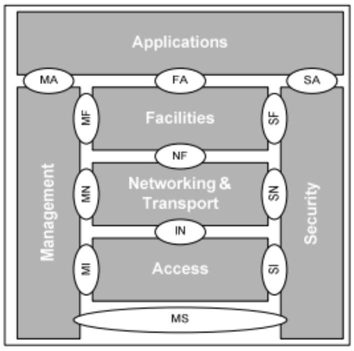

Figure 5 – ETSI ITS-G5 reference architecture [1]

For the network and transport layer, GeoNetworking protocol provides packet routing in ad hoc networks [7]. It supports the communication among individual ITS stations and the distribution of packets in geographical areas using broadcast.

On the application side, road/traffic safety related applications aim to reduce the risk of car accidents. They include cooperative awareness, in-vehicle signage, road works or hazard location warnings. These applications rely on the exchange of messages standardized by ETSI, like the following that were implemented:

- Cooperative Awareness Messages (CAM) – are periodic messages used to exchange information between ITS stations (e.g. vehicles, infrastructure) about time, vehicle type, dimensions, position, speed, heading, etc. By receiving CAM messages, other ITS stations are aware of its status, positions and movements used for getting traffic information, road and weather conditions status (e.g. sustained windshield wiper speeds).

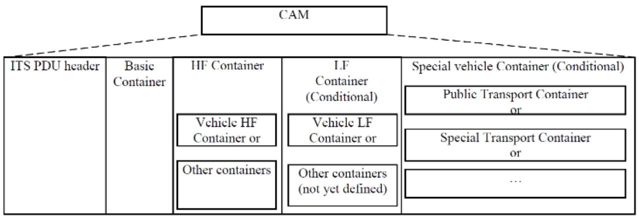

Figure 6 - General structure of a CAM [8]

- Decentralized Environmental Notification Messages (DENM) – are event triggered messages mainly used to alert drivers about Road Hazard Warnings (RHW) that have a potential impact on the road's safety and traffic conditions. They can be both generated by the vehicles through an HMI or through the TMC operator.

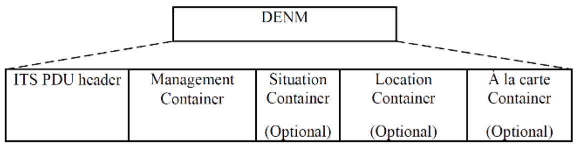

Figure 7 - General structure of a DENM [9]

- In-Vehicle Information Messages (IVIM) – are messages generated by the infrastructure to inform road users on static or dynamic road signs. The information is then received and displayed on the infotainment systems.

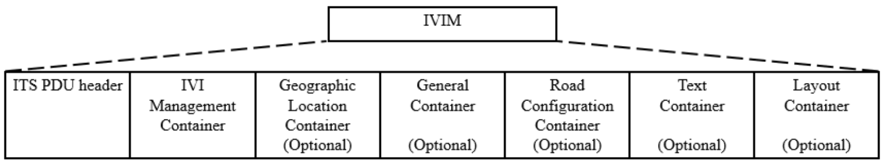

Figure 8 - General structure of an IVIM [6]

HMI Description

The onboard unit that goes inside the vehicle connects to an Android application running 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 placed by traffic management system. The following Figures present examples that are running in laboratory and real conditions, respectively.

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

III C-ITS Back-office

An efficient management of the C-ITS infrastructure involves interfacing and successfully share information and traffic events with several heterogeneous hardware and software modules. Moreover, A-to-Be has an innovative solution implemented for traffic management called ATLAS responsible for managing traffic events and process road incidents. Lacking the connection with C-ITS devices a new platform MOBICS (Mobility Intelligent Cooperative Systems) was built for managing the data exchanges between C-ITS equipment and existing road infrastructures.

It was adopted an open architecture running a rules engine, based on the Decision Modelling and Notation standard [10] that makes possible the cooperation with multiple central systems aiming for the removal of human intervention. This way the traffic management operator only sets the events on specific locations (like already does) and the system automatically routes to specific RSUs.
To monitor or debug individual systems, a pleasant web interface was created, capable of checking RSU status, setting rules for specific events, build/send standard messages by selecting a given RSU and filter out received events or awareness messages.
An example of the Dashboard page can be seen on the following image:

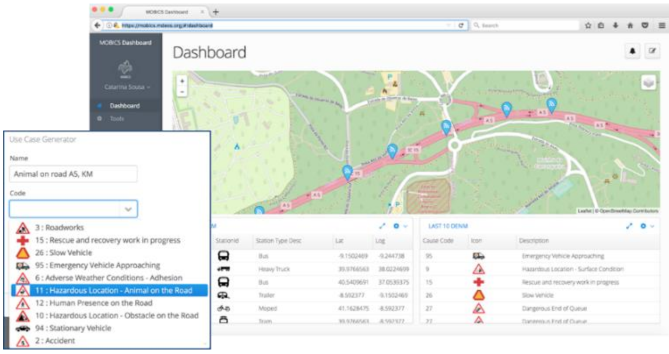

Figure 10 – MOBICS dashboard view with events and RSU locations

This management tool and its automatic rules engine brought the following advantages:

- real-time decision-making;
- robustness and effectiveness;
- less dependent on mistakes;
- dynamic adaptability capabilities based on its configurable feature.

IV European Projects Test Cases

The interoperability among different systems is the key for a large-scale C-ITS deployment. After cross checking the technical specifications with different countries and manufactures under the scope of different projects (e.g. ICSI, SCOOP@F Part 2, C-ROADS) extensive practical tests were performed to validate each of the standards implementation.

Cross tests for SCOOP@F Part 2 project

SCOOP@F is a Cooperative ITS pilot deployment project that intends to connect approximately 3000 vehicles with 2000 kilometres of roads. SCOOP@F is composed of SCOOP@F Part 1 from 2014 to 2015 and SCOOP@F Part 2 from 2016 to 2019. Its main objective is to improve the safety of road transport and road operating staff during works or maintenance.
A-to-Be is a partner under SCOOP@F Part 2 which includes the validation of C-ITS services in open roads, cross border tests with other EU Member States (France, Spain and Austria) and the development of a hybrid communication solution (3G-4G/ITS-G5).

Until now, three cross tests were conducted between the project partners in Vigo, Reims and Vienna [11]:

- Cross border tests (Vigo, Spain): Along a 10 kms corridor that goes through the Spanish-Portuguese border end-to-end interoperability tests were conducted to validate V2V and V2I communications. Some different approaches to message parameters were discovered and new technical specifications were written.

Figure 11 – Vigo use cases

- Security tests (Reims, France): A Public Key Infrastructure (PKI) was set in place to test just the security aspects and PKI configurations of V2V and V2I transmissions. The authentication of sent messages and their verification by the receivers were the main goals and were achieved with great success.

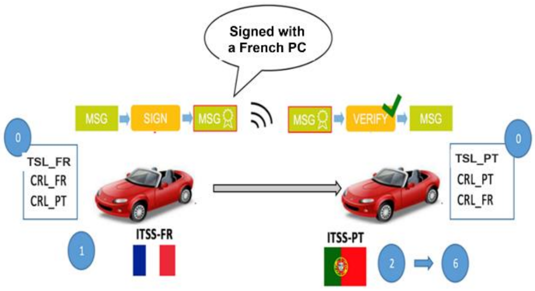

Figure 12 – Reims test diagram example

- Cross tests (Vienna, Austria): The main goal was not only to test end-to-end interoperability in real conditions, when the security infrastructure for ITS-G5 communications was activated, but also mitigate interference on protected communication zones. The HMI results matched the expected and no security concerns were detected leading to successful validation of the interoperability among partners. Likewise, protected zone messages were well received, and emitting power reduced.

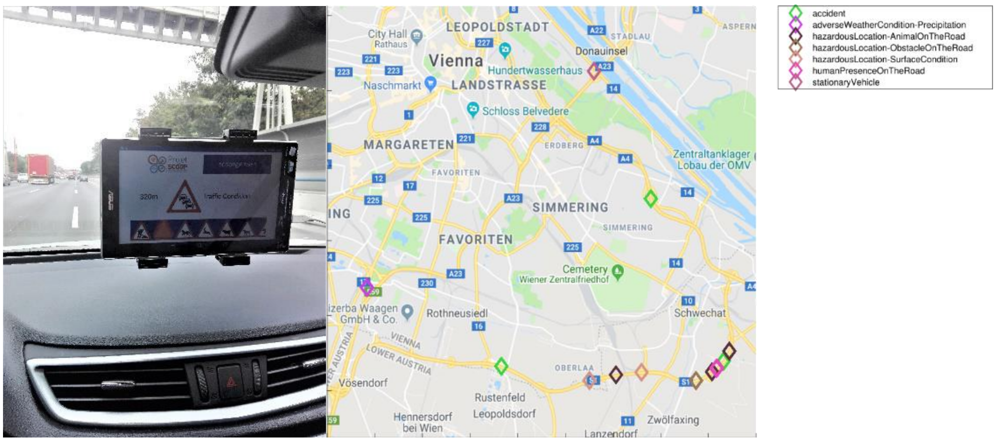

Figure 13 – A-to-Be's dashboard and data example on Vienna cross tests

Tests with Autonomous vehicles under AUTOCITS project

AUTOC-ITS is a project co-funded by the European Union aiming to contribute for the deployment of cooperative services, improving and promoting the use of C-ITS systems for connected autonomous vehicles (CAV). Under this objective it was planned 3 pilots on the Atlantic Corridor (Lisbon, Madrid and Paris) [12].

Brisa joined the consortium as an institutional partner and A-to-Be was responsible for the technology developments for the test. On the Lisbon pilot 6 RSUs were installed in highway A9/CREL and through the TMC different scenarios were simulated like obstacles on the road, adverse weather conditions, breakdown vehicle or road maintenance.

Figure 14 – Use cases and test vehicles on AUTOC-ITS Lisbon pilot

The major part of the vehicles received the simulated events and adapted their behaviour automatically close to the hazard location. Furthermore, A-to-Be's traffic management system was able to track in real-time the CAVs status and motion.

V Final remarks

This paper described the C-ITS framework solution developed by A-to-Be and its partners and showed several test case scenarios implemented in real conditions with great levels of success.

Nevertheless, the ambition is to incorporate new communication technologies (e.g. cellular networks) for providing road users and manufactures more flexible ways of interacting with the infrastructure. This work is currently in progress and will be validated in the next cross-border trials held in Portugal under SCOOP@F Part 2.

Additionally, C-ROADS Portugal started in 2017 consisting on the large-scale deployment C-ITS services on 5 macro pilots where new use cases will be designed and verified.

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