ON BOARD COMMUNICATIONS PLATFORM FOR SERVICES DEPLOYMENT IN VEHICLES

Bottom-up approach for Intelligent Transport Systems deployment

Unai Hernández-Jayo, Ignacio Angulo, Asier Perallos, Nekane Sainz
University of Deusto, Avda. Universidades 24, 48007 Bilbao - Spain
unai.hernandez@deusto.es ignacio.angulo@deusto.es perallos@deusto.es nekane.sainz@deusto.es

Keywords: Vehicle embedded systems, VANET, OBD, V2V/V2I Communications, and Intelligent Transport Systems.

Abstract: This paper reflects the advances and results of two research projects supported by the Basque Government. The objective of this work is to build a device which allows the driver to communicate with his vehicle, with other vehicles and the infrastructure on the road. This Intelligent On Board Unit will be able to learnt from driver behavior and the environment. Based on this knowledge, the I-OBU could advise the driver on actions to take while driving.The modules implemented and the test scenario that has been built to validate the proposed architecture, are shown in this article.

1 INTRODUCTION

The new information technologies and communications applied to intelligent transportation systems can improve transportation efficiency in areas such as safety, pollution or infotainment. To give the vehicle the ability to communicate with other vehicles (V2V) or infrastructure (V2I) enables the deployment of many services designed to improve the quality of passenger transport, safety or reducing contaminant emissions (Chisalita, 2006)

Moreover, the continuous emergence of new digital content services for the automotive forces the user to add different “gadgets” to the vehicle covering some needs over time become essential. Navigation systems, hands-free or portable media devices are among the top selling devices at any appliance store.

In addition, the European Commission has prioritized the implementation of the Green Car initiative which aims to fund research into sustainable road transport.

In this paper, the work of the Intelligent Transport research group from the University of Deusto in the area of vehicle embedded systems is shown. First, projects focus on this area of application are enounced, making special mention on projects recently approved by the European Union. In section 3, the proposed platform is described, and in section 4, each block of this platform is explained. Finally, the future work and conclusions are presented.

2 RELATED WORK

Except some initiatives emerging for certain manufacturers, such as The Genivi Alliance (Macario, 2009), there is not a on-board platform with an open architecture. There is not any system able to provide access to information from inside the vehicle, from external infrastructure or even from other vehicles and also support the implementation of services, consumers of such information relating to any of the areas of intelligent transport.

There are various initiatives and European research projects in this area. The most significant are summarise below:

CVIS (Cooperative Vehicle Infrastructure Systems): Coordinated by ERTICO, this project focuses on providing cars with a technology solution capable to communicate securely with other vehicles (V2V) and with the nearby roadside infrastructure (V2I) (Toulminet, 2008). Although the project includes developing a framework for open application management, is focused primarily on core cooperative technology.

SAFESPOT (Cooperative systems for Road Safety): This project provides a platform capable of obtaining information from inside the vehicle and from sensors arranged on the road. It is coordinated by the Fiat Research Centre and offers a solution designed exclusively to detect critical driving situations aimed at improving safety in road transport (Toulminet, 2008).

COOPERS (Cooperative systems for Intelligent Road Safety): This project, coordinated by Austria Tech, proposes to connect the vehicles through continuous wireless communication with the road infrastructure to provide services that improve driving safety (Toulminet, 2008).

m:Via-Future of the Intelligent Transportation Systems: Led by Telefónica I+D, this project focuses on the use of networks and mobile or wireless technologies to increase road safety and add value as infotainment, vehicle support, comfort and traffic optimization (García, 2009).

Main difference between the solution proposed in this paper and those mentioned above are mainly based on bottom-up approach adopted in this project. Instead of doing the analysis of requirements from the services to be developed, this project focuses on developing a general platform, capable of obtaining information from inside and outside the vehicle, over an open and scalable architecture on which to deploy all services related to intelligent transportation.

3 PLATFORM PROPOSAL TO PROVIDE INTELLIGENT TRANSPORTATION SERVICES

As it was described previously in section 2, many initiatives have arisen with the aim of providing connectivity between the cars and their environment, in order to deploy new intelligent transportation services. The challenge is to provide connectivity, intelligence and real time information to mobile elements (vehicles) in a lacking of connectivity enviroment. Moreover, in this scenario many elements play as sources and destinies of information: other vehicles, road infrastructure, driver and passengers, traffic management centers, and so on.

Therefore, a system like this should include on board elements and those systems placed on the roadside. Related to the on board system:

- It is necessary that the system will be able to collect data from the vehicle data buses . For example, these data can be used for remote monitoring.
- Interaction with and integration other on board devices and gadgets is a desired capability too. Nowadays it is a common practice that many devices were placed on board (GPS/navigator, free hand systems, multimedia player, and so on). Likely, more and more gadgets will be launched in the following years. The proposed system might be able to establish communication with them and integrate its functionality into a single device. This system works as a concentrator of current on board devices and gadgets and some others that could arise in the future (for example, a set of wireless network sensors installed inside the vehicle).
- A particular in-vehicle element is the driver and the passengers, because of the way in which the system will interact with them. Thus, on board system has to provide a human machine interface (HMI) compatible with the driving. It enables the provision of information by users to the system as well as the consumption of the services by them.
- Finally, communications with externals elements (Vehicular Ad-Hoc Network - VANETS) are needed in order to broadcast internal data and to access to external services. It might support a wide range of wireless communications technologies to fulfill the interaction requirements with all the external elements.

These specifications might be supported by a hardware device which hosts the in-vehicle embedded system. Both elements (hardware and software) will constitute the classic On Board Unit (OBU) which is shown in ITS architectures. As well, this hardware device has to fulfill some requirements: low consumption and price, wide range of communication interfaces, independence of the car maker, non-intrusive design and driving compliance human interface. Furthermore, it should be based on an open software platform to allow adding new services. This makes the system scalable and flexible for future developments.. Then, a framework for the development and deployment of new services should be included. The functional components of the OBU's architecture are shown in Figure 1.

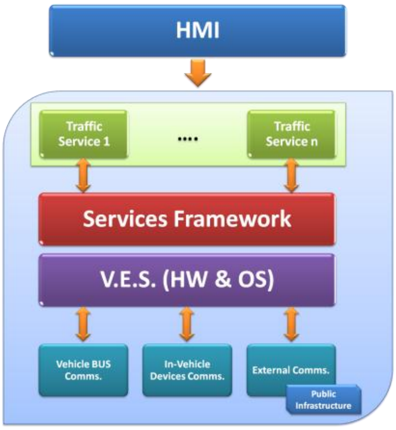


Figure 1. Functional components of the On-Board Unit architecture

Related to the road infrastructure systems, elements which provide wireless communications access point along the road are needed. Moreover, some process to analyze the data sent by the OBUs and to transfer them towards the traffic related information systems are required. These elements are named Road-Side Unit (RSU). Finally, the infrastructure which hosts these traffic information systems is needed. This infrastructure, which acts as a gateway between final applications and the mobile networks nodes, will aggregate the information provided by the mobile environment (the vehicles) and use it to provide advanced traffic services and applications. Figure 2 shows the current subsystems and connections between them in a classic ITS architecture for surface transport.

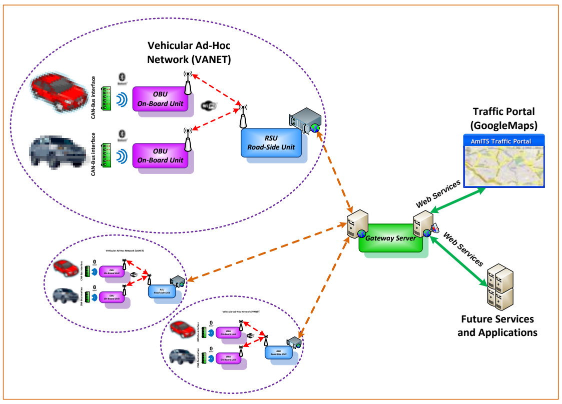
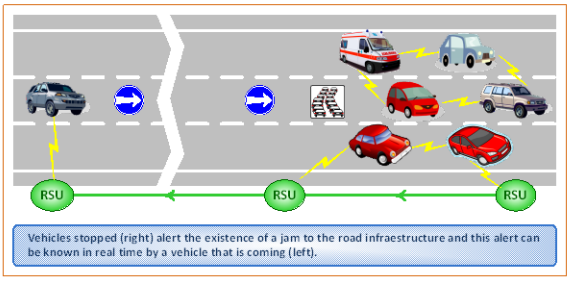


Figure 2. Components and communications in a classic ITS architecture for surface transport

Once the proposed architecture is deployed in a real scenario, there is a wide range of services that could be provided. For example: remote monitoring services based on data acquired from the vehicle (consumptions, temperature, and so on), fleet management services, driving assistance services (i.e, recommended routes or alerts warnings), traffic management services, assistance services used by the entities which manage the road infrastructures and traffic (councils, for example) or passenger information services (infotainment, tourism and advertisement). Some of these services will be accessed through web portals or fat clients at home or in the management centers. Other applications will be accessed from car.

In the test scenario designed to check the ITS platform described in this paper, a particular service for traffic alerts broadcasting has been considered. In this service drivers can report real time information about the road state and special events, as well as their position, while they are driving. Some of the alerts or especial events considered are: a prioritized vehicle (policy, ambulance or firefighter) is coming, a vehicle driving on opposite direction is coming, an accident has happened, adverse meteorological conditions and nearing to a jam. Figure 3 shows a use case where a jam alert is broadcasted.



Vehicles stopped (right) alert the existence of a jam to the road infraestructure and this alert can be known in real time by a vehicle that is coming (left).

Figure 3. Jam alert broadcasting.

This information is available in a traffic portal. This site informs about the state of the traffic in a selected geographical region.

4 CURRENT DEVELOPMENTS

To check the platform described in the previous section, specific modules have been developed. Finally, we have built a test scenario to validate proposed architecture. Those modules and this scenario are presented in the following paragraphs.

4.1 Developed modules

Two types of modules have been developed: those that are on board the vehicle and those modules that are out of it, that is, the modules that are placed on the road or in a control center.

A prototype of On board Unit (OBU) has been developed (Figure 4). Thanks to this prototype, the user will be able to receive data: a) from the vehicle; b) from the gadgets inside the vehicle (PDAs, cellular, sensor networks, etc.); c) elements placed out of the vehicle; d) from the user, thanks to a Human Machine Interface.

This OBU can be used in any kind of vehicle, regardless of the manufacturer and it must be easily placed inside the vehicle by a user without special skills. Apart of those characteristics, new and future services can be added in a transparent way for the user. Preexisting services and gadgets could be added too.

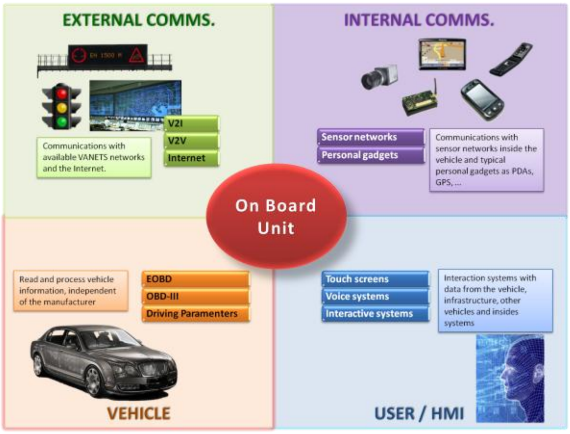


Figure 4. On Board Unit description.

Out of the vehicle, some applications have been developed to receive data that are sent from the vehicle. Those data are collected in a control unit and are used, i.e., to control the traffic in an area, to fleet management, to know the situation of special vehicles, etc.

4.1.1 Communications with the vehicle

One of the goals of this project is that any user can use the platform that here is presented. As well, the control center or the user can obtain data from the vehicle either in real time or those data can be saved in a file.

To satisfy both requirements, we are working with the standard OBD-II (Lebert, 2001). Thanks to this standard, data are running in the bus can be sniffed and the user can access to this information.

There are three basic OBD-II protocols in use. While there have been some manufacturer changes between protocols in the past few years, as a rule of thumb, Chrysler products and all European and most Asian imports use ISO 9141 circuitry. GM cars and light trucks use SAE J1850 VPW (Variable Pulse Width Modulation), and Fords use SAE J1850 PWM (Pulse Width Modulation) communication patterns.

To communicate the OBU with the data bus in the vehicle, a Bluetooth interface has been used. This is a commercial device and thanks to it, this communication is transparent for the user.

Using this interface, the user can collect data related with the vehicle: speed, revolutions, fuel level (load), and engine temperature and so on. This information can be shown in a graphical interface (Figure 5) or be saved to analysis later.

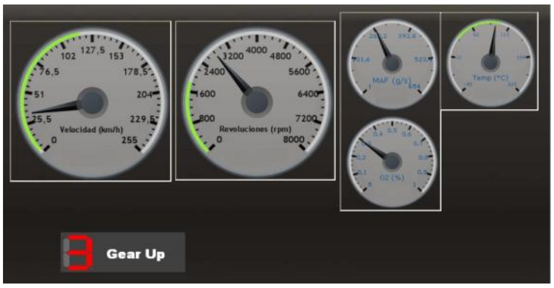


Figure 5. OBD graphical interface.

Using this information from the mechanic and electronic of the vehicle, software applications can be developed. For now, one service focus on *eco-driving* has been developed. Knowing the engine torque and reading the speed and rpm, this service recommends the user the best speed gear ratio. Thus, the fuel consumption and CO_2 emissions can be reduced.

As well, using a GPS system, the user or a remote controller (placed in the headquarters, i.e.), can obtain the relation position-driving parameters in each point of the followed route. This information serves to make more checks on a fleet of vehicles or can be used by the user to draw conclusions about his behavior during the route (average speed, consumption, emissions, etc.).

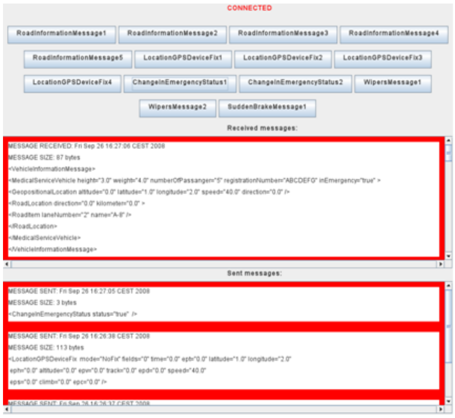
4.1.2 External communication

Using the wireless communications systems that OBU implements, the vehicle can interchange information with elements placed on the road. These elements and the vehicles create a Vehicular Ad-hoc Network (Ducourthial, 2009). Traffic lights, traffic signals, information panels or other devices which collect data from the road could implement a communication system and send data to the vehicles or to a central server through a Road Side Unit (RSU).

The objective of the external communications module is that the user be reported with real time information about the road state and special events. This information has to be shown inside the vehicle, so OBU has to implement an interface to read and display these data. For example, special vehicles as ambulances, police or firefighters can generate alerts to inform about their situation and route. This information is received by the RSU and it sends it to the central server. Then it is resent to all the vehicles in the area of the alert. The user, inside the vehicle, receives the alarm in the OBU and it shows a special event in the GPS screen. Then, the user could take appropriate actions.

Right now, this module is based on point to point communications: the user can send events to the central server with his cellular (uplink). When the server receives the event, this is shown in a traffic portal. Presently, we are developing the downlink to inform others vehicles of the events generated by one user.

Figure 6 shows the simulation of the communication between a vehicle and a RSU that resends the information to the central server. The central server receives the data, and it displays the alerts in the web application (traffic web site)



```
MESSAGE RECEIVED: Fri Sep 26 16:27:06 CEST 2008
MESSAGE SIZE: 87 bytes
<VehicleInformationMessage>
<MedicalServiceVehicle height="3.0" weight="4.0" numberOfPassanger="5" registrationNumber="ABCDEFG" inEmergency="true" >
<GeopositionalLocation altitude="0.0" latitude="1.0" longitude="2.0" speed="40.0" direction="0.0" />
<RoadLocation direction="0.0" kilometer="0.0" >
<RoadItem laneNumber="2" name="A-8" />
</RoadLocation>
</MedicalServiceVehicle>
</VehicleInformationMessage>
```

```
MESSAGE SENT: Fri Sep 26 16:27:05 CEST 2008
MESSAGE SIZE: 3 bytes
<ChangeInEmergencyStatus status="true"  />

MESSAGE SENT: Fri Sep 26 16:26:38 CEST 2008
MESSAGE SIZE: 113 bytes
<LocationGPSDeviceFix mode="NoFix" fields="0" time="0.0" ept="0.0" latitude="1.0" longitude="2.0"
 eph="0.0" altitude="0.0" epv="0.0" track="0.0" epd="0.0" speed="40.0"
 eps="0.0" climb="0.0" epc="0.0" />

MESSAGE SENT: Fri Sep 26 16:26:37 CEST 2008
```

Figure 6. Communication between the car and road side unit.

4.1.3 Internal communications

As it is described in the previous section, the user can generate information from his vehicle and send it to the VANET. To give out his information, he has instruments to transmit events inside the vehicle.

Sensor networks can be deployed inside the vehicle. These can be used to monitor the driver's physical parameters (heart rate, temperature, etc) (Nakanishi, 2007). The data from these networks could be collected by the OBU for a later analysis.

Users’ gadgets as PDA or cellular can be used as an interface to generate information or to receive data from the vehicle or the external devices. Thanks to these devices, the user can export data to his laptop at home and register all the information generated in a journey.

As you can see, may have different sources of information inside the vehicle. Therefore, it is necessary to have a device to handle all communications and serve as a gateway to the user to interchange data with these elements.

4.1.4 Human Machine Interface

The main requirement is that the HMI interface is interactive and non-intrusive, that is, it should be used by the driver while driving.

Currently, the developed OBU implements a touch screen that restricts their use when the car is moving, but we work to incorporate a voice system to it.

4.2 Test Scenario

To validate both the OBU and the elements developed to be outside the vehicle, a test scenario is designed (Figure 7) in which the operation of these elements has been validated and verified.

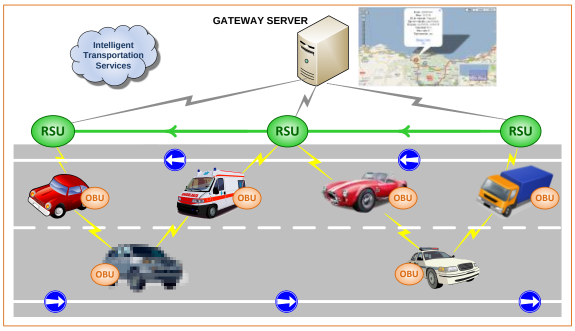


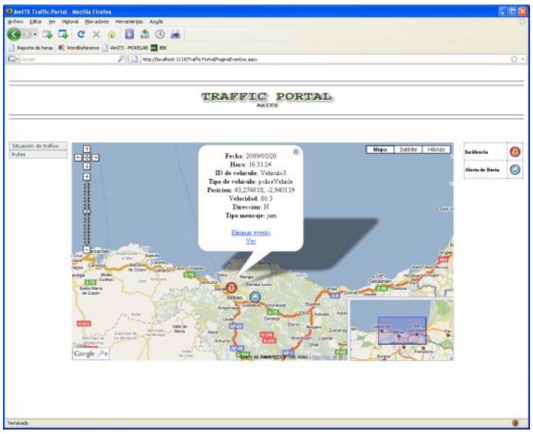
Figure 7. Test Scenario

4.2.1 Traffic Site

For this scenario, a traffic site has been created. On it, the information of each vehicle connected to the system is showing.

Of each vehicle can get the position, the route and the type of vehicle, a unique identity and its speed. We distinguish different types of vehicle: common vehicle, ambulance, emergency ambulance, emergency vehicle (fire, police).

In addition, each of these vehicles can report incidents such as traffic jams, accidents or heavy rains. These events are reflected in the traffic portal with its position, time and date (Figure 8).



Fecha: 2009/01/20
Hora: 16:31:24
ID de vehículo: Vehiculo3
Tipo de vehículo: policeVehicle
Posicion: 43,274618, -2,940119
Velocidad: 80.3
Dirección: N
Tipo mensaje: jam

Figure 8. Traffic portal

4.2.2 OBD data collection

To access the data running through the vehicle communication bus, Bluetooth interface is connected to the connector OBDII in the vehicle (Figure 9). Then, the information is sent to the device that has played the role of the OBU.

Then, these data are analyzed and either they are displayed using a graphical user interface or they are stored. These stored data can be analyzed or sent to the traffic site which can keep track of these parameters. Figure 9 shows a test to validate the communication between the OBD and the laptop that plays as the on board OBU.

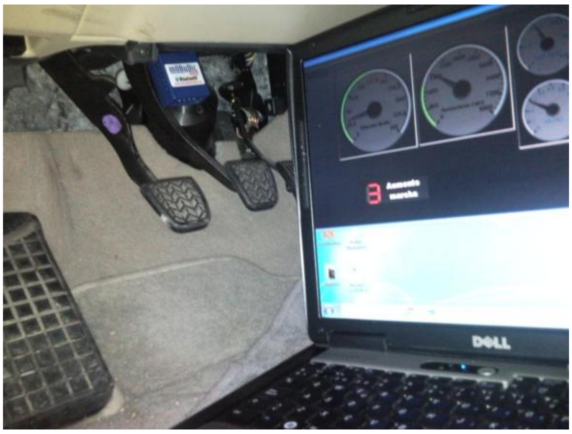


Figure 9. Bluetooth interface on board and simulated OBU

4.2.3 VANET simulation

Moreover, using the NS2 network simulator (Kubinidze, 2006), the performance of communications between a moving vehicle and the RSU has been simulated.

In this simulation, a vehicle sends periodically an alarm message to the RSU. The vehicle could be for example an ambulance, and it is moving through different areas under different RSU's coverage. The objective of the simulation is to measure how successful any RSU within the area receives the messages in order to guarantee the alarm message reception.

To perform this scenario, an event generator has been simulated on board. The Figure 10 shows the dashboard and the buttons that user can push to send message to the traffic site.

Figure 10. On board event generator dashboard.

The scenario simulates a two-way roadway. The RSUs are placed in both sides of the road. There is a random number of vehicles circulating in both directions and the ambulance goes all over the road from one extreme to the other. During its way, the ambulance sends periodically the same alarm message.

In Table 1, some results for different RSU separations are shown.

Table 1. Simulation results for different distances

RSU separation (m)	Package reception percentage (%)
500	79.3
400	100.0
350	82.6

According to data shown in Table I, a separation of 400m seems to be the ideal distance between

RSUs. If the RSUs are placed closer, overlapping areas appear and alarm messages are detected by two different RSUs. More than 400m of separation do not guarantee a 100% package reception.

5 FUTURE WORK

Currently we are working to increase the amount of data read from OBD. With these data will improve the eco-driving service and provide other services like remote diagnostics and monitoring vehicle maintenance. As well, we are analyzing how we can use the communication bus in the vehicle to obtain specific information of electrical vehicles. With this information we will provide services geared exclusively to electric cars.

To test the external communications, we are implementing the downlink between the traffic site and the vehicle. In this way, the user will be reported with traffic information and special events in real time.

We are studying which sensor networks can be used to monitor the driver's physical constants and which services can be offered with this information.

The HMI module is the less developed, so we are working to improve the interactivity in a non-intrusive way using voice recognition systems.

Finally, the proposed platform must be test in a real scenario.

6 CONCLUSIONS

All of the projects presented in the state-of-art of this article, are based on top-down approach. That is: the ITS architecture is designed from the point of view of the services. Once the services are designed, the hardware platform is developed. The problem of these approaches is that they are no easily scalable, because new services may require new hardware. Most of the times, change the hardware design is difficult and expensive.

However, the on board platform presented here, is designed following a bottom-up approach. First, the hardware is designed to support different type of services. This hardware meets the characteristics necessary to support new and future type of services.

The goal of this initiative is to deploy an on board platform with several communications interfaces and develop services to validate it. Some of those services are shown in this article (event generation, eco-driving, and so on).

Add new capabilities to the platform, create new services based on new V2V and V2I concepts, and finally, check the whole system (platform and services) in a real scenario are the objectives of the following steps.

ACKNOWLEDGEMENTS

This project is financially supported by Basque Country Government under the Saiotek, Gaitek and Bizkaiberri funding programs (PE07FD03, IG-2009/0000188 and 12/72/2009/258/1).

REFERENCES

Chisalita I. And Shahmehri N., 2006. *Emergency Information Dissemination in Mobile Networks for Vehicles*. In *International Conference on Wireless Information Networks and Systems. WINSYS2006*.

Macario, G., Torchiano, M. and Violante, M., 2009. Industrial Embedded Systems, 2009. SIES apos;09. IEEE International Symposium on. Volume , Issue , 8-10 July 2009 Page(s):257 - 260

Toulminet G., Boussuge J., And Laurgeau C., 2008. *Comparative synthesis of the 3 main european projects dealing with cooperative systems (cvis, safespot and coopers) and description of coopers demonstration site 4*, Intelligent Transportation Systems,2008. ITSC 2008. 11th International IEEE Conference on (2008), 809-814.

García L., Pinart C., Lequerica I., Alonso A., Rodríguez J. J., González J.M. And Quesada D.,2009, *m:Vía, an ims-based approach for turning vehicles and roads into a smart envinronment*, 16 ITS World Congress 2009,Stockholm (Sweden).

Lebert, K., Pillin, M., 2001. *Advanced HiL systems for OBDII functionality testing*. 2nd International Automotive Conference, Brighton, England.

Ducourthial, B., Khalfallah, S., 2009. *A platform for road experiments.* 69th IEEE Vehicular Technology Conference, Barcelona, Spain.

Nakanishi, AYJ; Western, BJ., 2007. *Advancing the state-of-the-art in transportation security identification and verification technologies: Biometric and multibiometric systems*. 10th International IEEE Conference on Intelligent Transportation Systems, Bellevue.

Kubinidze, N; Ganchev, I; O'Droma, M., 2006. *Network simulator NS2: Shortcomings, potential development and enhancement strategies.* Symposium on Modeling and Simulation Tools for Emerging Telecommunications Networks. Falkultaet Inform Univ Bundersweh, Munich, Germany.