A set of driver assistance services ready to be deployed on board

Unai Hernández-Jayo
Deusto Institute of Technology
Av. Universidades 24 48007 Bilbao-Spain
unai.hernandez@deusto.es

Nekane Sainz Bedoya
Deusto Institute of Technology
Av. Universidades 24 48007 Bilbao-Spain
nekane.sainz@deusto.es

Isabel Iglesias Pallín
Deusto Institute of Technology
Av. Universidades 24 48007 Bilbao-Spain
isabel.iglesias@deusto.es

Iñigo Zumalde Gallego
Deusto Institute of Technology
Av. Universidades 24 48007 Bilbao-Spain
inigo.zumalde@opendeusto.es

Daniel Jimenez Reyero
Deusto Institute of Technology
Av. Universidades 24 48007 Bilbao-Spain
dani.jimenez@opendeusto.es

Maria Pilar Elejoste Larrucea
Deusto Institute of Technology
Av. Universidades 24 48007 Bilbao-Spain
pilar.elejoste@deusto.es

Abstract— **This paper describes the work-in-progress in the topic of the driver assistance services. The Mobility research group of the Deusto Institute of Technology has been working for the last two years in the development of services focused on improving the security and safety of both drivers and passengers. These services are described in this paper.**

Keywords-component; driver assistance services; VANET communications;eco-driving; real-time video processing

I. INTRODUCTION

The new information technologies and communications applied to intelligent transportation systems can improve transportation efficiency in areas such as safety and infotainment. Moreover, today's society is particularly sensitive about the environment so ICT can be used to help drivers to reduce fuel consumption during driving.

Furthermore, few years ago, vehicles were only used for transportation, but nowadays drivers spend much more time inside of them, so it is necessary to increase access to information related to the surrounding environment (infotainment), and to provide elaborate and timely information to help driver to make decisions while driving.

To obtain functional services that could be easily and fast deployed in a vehicle, Mobility research team has divided the driver assistance topic into three different areas, which are explained in the following sections. Section II is focused on the development of a communications network based on IEEE 802.11p wireless standard that defines the techniques and protocols to support Intelligent Transportation Systems on vehicles. This VANET (Vehicular Ad-Hoc Network) will be used to deploy safety services in a real scenario. The aim of Section III is to develop a set of services to provide the driver with a) information in real time about his/her route to destination and b) recommendations and statistics to improve the driving experience in order to reduce fuel consumption and CO2 emissions. In Section IV, services based on real time video processing are explained. With these backup services, the driver is warned about different events that could happen during the driving (road lanes change detection, obstacle detection, and so on). Finally, conclusions and future work is presented in the Section V.

II. REAL VANET SCENARIOS

Deploying a new service based on a new and not mature technology is necessarily complicated. Even harder when, in order to check its correct behaviour, a large number of interoperating nodes or a well established infrastructure is required.

For that reason, in many cases it is necessary to base previous research on a simulation of the scenarios before any Field Operational Tests (FOTs) can be done. Anyway, having to choose a simulator for C2X-Communications is not always an easy task. Many of them are very powerful but lack the necessary implementation of the standard so it has to be developed or bought, with the cost or the time attached to such proceedings. Most of the simulators consist of different software modules which are responsible for simulating some specific protocols. Those modules can be bought in some cases but sometimes they simply do not exist and therefore have to be programmed if the simulator is prepared for it.
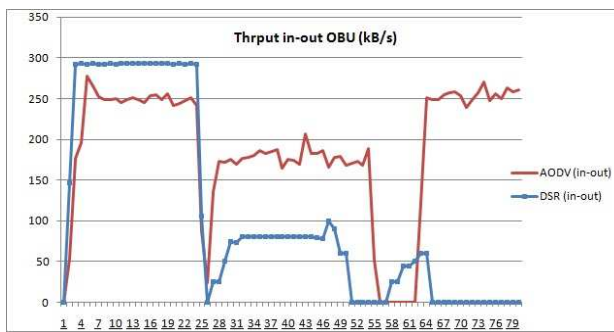
Figure 1. Simulated OBUs throughput

A. First Steps: communication simulations

For that reason and taken as a basis a previous study [1], it was decided to lead a series of simulations on NCTUns 6.0 simulator. This software requires a specific Linux kernel so that it can use the protocol stack of the operating system. This technique makes the simulations more reliable, as the packets being transmitted within the multiple scenarios travel through an authentic protocol stack. Another important aspect of this simulator is that it offers the researcher the possibility to test their software, both networking applications such as protocols, or just desktop applications configured to use the simulator, as it provides a common interface to that purpose.

The first attempts with this simulator were headed in order to compare the differences between installing and deploying an IEEE 802.11p network between cars and letting them form ad hoc networks based on IEEE 802.11b [2]. This comparison gave the expected results: the p standard was more reliable, gave a much better time response and a higher throughput, being it less dependent of the speed of nodes

Afterwards, an analysis of the routing protocols was undertaken, and tested to determine whether typical ad hoc networking protocols were good enough for a Car-to-Car Communication or not. For that purpose, a comparison between AODV and DSR was launched. The first of which, came as better option for this kind of network (Figure 1). The simulated scenario focused on an OBU traveling through different RSU-based wireless networks and how the changing from an Access Point (AP) to another had a consequence in the throughput and packet loss. AODV turned to be much more reliable, gave better throughput in all cases and the number of unicast packets send by the RSU are down to 50% when compared to the ones send by RSU operating with DSR.

B. Developing a real scenario

For taking the simulations into practice, the current work is centered on operating with two NEC LinkBird MX modules (Figure 2)

Other alternatives were taken into account such as [3]. It proposes a full-stack prototype implementation to data exchange among vehicles based on FPGAs. This was discarded in favour of the commercial solution offered by NEC.

Figure 2. NEC Linkbird MX

These modules present a great variety of interfaces for communicating in the 5.9GHz band. A 30MHz band was allocated by the ETSI for Intelligent Transport System to use it in Car-to-Car and Car-to-Infrastructure (C2X) communications centered in the 5.9GHz band [3] . The technology is founded on ad hoc networking, using protocols based on knowing the position of nodes rather than their situation in the topology. The so called "Geocast" routing protocol, assumes that vehicles acquire information about their position (i.e. geodetic coordinates) via GPS or any other positioning systems [4]. Routing becomes a matter of knowing where the target is located, and then forwarding packets so that in each hop, they get closer to their final location. For that purpose each node keeps track of other node's position in a table.

The LinkBird MX modules, with their compact size and communication capabilities offer a great chance to test whether the simulations where correct and to emulate some scenarios in a way that is much more realistic than the one presented on the simulations.

In order to evaluate the performance of these modules in a close real situation, it was decided to regard one of them as being a Road Side Unit (RSU) offering a service such as those referred to as Infotainment , and the other module as being part of the On Board Unit within a car. Starting sufficiently far from the RSU and getting closer, it was possible to determine the association time needed to establish a connection between both modules. As a sub product of these experiments it was also possible to determine antennas coverage, signal level threshold for a communication to be established etc.

The original idea of introducing applications in the On Board Unit was recently discarded. Nearly every user will have a Smartphone with the capabilities to run resource-demanding applications such as those needed for the Safety or Infotainment services, which will be developed in the near future. These applications should be able to access the On Board Unit creating a Wireless Personal Area Network (WPAN) such as a Bluetooth based communication, to then access the rest of the network.

Further experiments will focus on the one hand, on the possibility of handing over a dataflow from an IEEE 802.11p based network to an IEEE 802.11g one. This scenario represents the Infotainment point of view of Car-to-X

communications. An example of this kind of communication is proposed by Marica Amadeo et al [5]. On the other hand, other set of experiments are going to be focused on Safety. In this later case, the throughput and handover tend to be less relevant but delays and latency between safety applications becomes critical. Both scenarios require a similar architecture but in order to start with the FOTs a deep analysis of the situation must be performed so as to have at least an idea of what results should offer the implementation in terms of BER vs speed and latency vs speed.

III. DRIVER ASSISTANCE SERVICES

The new information technologies and communications applied to intelligent transportation system can improve transportation efficiency in areas such as safety, environment or infotainment.

Our aim is to provide the driver with information about the road situation and a mechanism to obtain the best travel route to avoid traffic jams. This will reduce travel times, car congestion and greenhouse gas emissions by car.

The next objective is to deploy these services in a smart phone.

A. On board traffic information service

Every day 53% of drivers are affected by traffic jams around big cities, and spend an average of 14 minutes per day on their cars stopped.

Including a real time traffic information service on the vehicle allows the driver to have valuable information. As a result of the service's advantages, it is possible to reduce the number of crashes, traffic jams, waiting time and fuel afford.

To develop this service it is necessary to gather the information from different traffic information servers. Then, users could have real time access to all relevant data concerning the road conditions through a wireless connection. In our case, this information is obtained by the traffic portals of different public organisms such as www.trafikoa.net, supported by the Basque Government.

All this information will be shown on board superimposed on a GIS map. So, once users mark the destination, they could select and view all relevant information items about the route they will take, as traffic jams, accidents, works on the road, bad conditions of the road, etc.

Additionally, users can obtain images from different traffic cameras located on most important roads of the country. This enables drivers to have access to this information in a real and accurate mode (Figure 3). The system works as a traditional GPS. Users before setting out could indicate their destination and the application will show the best routes for the trip with different indications. All travel information obtained from the main traffic authorities will be shown; traffic jams, traffic intensity, roadblocks, estimated travel time, average speed, and occupation level and so on.
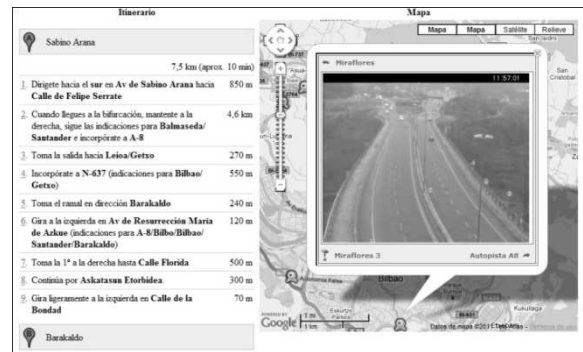

Figure 3. Information from traffic cameras

This information allows the user to know the traffic conditions before setting out, so drivers will save time preventing possible bad road conditions and traffic jams that could generate.

This service works on a car-pc but it is able to be deployed over a smart phone, working as the HMI of the system.

B. Eco-driving service

Nowadays, the information provided by the vehicles sensors makes it possible to offer to the drivers services orientated to reduce the consumption of fuel and related CO_2 emissions. It also decreases acoustic pollution caused by the vehicles´ engine.

This set of services are called eco-driving services and their purpose is to help the vehicle user to obtain a more sustainable, comfortable and efficient conduction. This new way of driving aims to achieve: decrease fuel consumption, reduction of environmental pollution, increase driving comfort and decrease risks on the road.

According to the Institute for Diversification and Energy Saving (IDAE) [6], the Spanish cars spend 15% of the total energy consumed in the country. In addition, 40% of CO_2 total emissions come from road transportation. These high rates indicate that vehicles should be driven more efficiently.

It is important to emphasize the main advantages of doing an efficient driving, which are visible in different areas:
1) Average of 15% on fuel saving
2) Urban pollution reduction that improves the breathed air.
3) Reduction of greenhouse emissions that improves the atmosphere warming problems.
4) Energy savings on a national scale.

To develop this service, we are working with the standard OBD-II [6], specifically using OBD-II and ECU simulator. The work in progress presented in these lines is already under test, so it is being tested in laboratory that is the reason of using an Electronic Control Unit (ECU) simulator instead of a real car. Thanks to this standard, data running in the bus can be sniffed and this information can be analyzed by the user.

To communicate the On Board Unit (OBU) with the data bus in the simulator, a Bluetooth interface has been used. This commercial device makes the communication transparent for the user.

Using this interface, the user could collect data related to

the OBD simulator: speed, revolutions, fuel level (load), engine temperature, CO_2 emissions and so on. It also provides different fault stored codes of the system which warn the user of potential system failures.

In this way, it is possible to recreate many incidents scenarios that will be useful for project´s development and events simulations.

Once data is received, the OBU interprets it, combines it if necessary and shows the information to the driver through a graphical interface with different gauges (Figure 4).

The goal of the eco-driving service is to alert the users when their driving it is not being efficient and it is prepared to display different advices to improve the driving. This service recommends the best speed gear ratio to the driver, volume of CO_2 emissions or indication of unnecessary accelerations and brakes in real time.

The main difference between the system described here and other ones is that in this case, the obtained data is taken from the vehicle itself, without the necessity of doing estimations based on GPS or other systems.

The user interface developed is divided in four key areas:

1) Real time variables: thanks to these gauges, the driver can control the data related to the driving: speed, revolutions per minute, percentage of O_2, fuel level, and CO_2 emissions.

2) Recommended gear: the driver gets the system recommendation to use the right gear all the time. Thanks to the combination of the speed and rpm values obtained through the OBD interface, the optimum gear is calculated and displayed in the interface.

3) Acceleration and braking notification: drivers are advised when abrupt acceleration or braking are detected. The system determines this through the difference between the revolutions per minute in real time and the value obtained of this variable in the previous reading. If the obtained value exceeds 20%, panel with the appropriate indicator will turn red
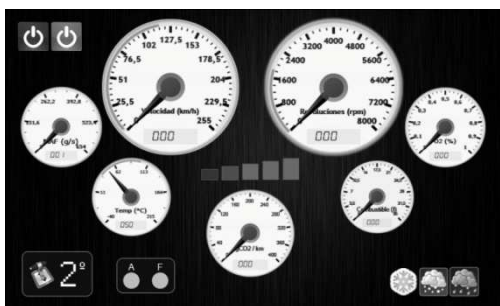

Figure 4. Eco-driving graphical interface

4) CO_2 emissions: in addition to real-time meter of emissions, the system features a color LED display. Through this system of color, ranging from green to red, the user knows how well its driving behavior on emissions is. When the green LEDs are on, the driver knows that the car emissions are under the threshold

provided by the manufacturer. If the orange LEDs are on, the emissions are near to this threshold. Finally, red color displays that the calculated emissions value is over this threshold. In this situation, the driver should reduce the speed to lower emissions. The threshold used to determinate the LEDs' color has been established using the European Union normative: 140 grams CO_2 per kilometer. In 2012, this threshold will decrease to 120 grams CO_2 per kilometer.

The information gathered by the OBU could be stored for later studies or analysis. Data captured can be configured by the user. All relevant driving variables will be stored on a XML file, so drivers could review all their historical data and improve their driving at the future.

Users can also view the evolution of their driving with different statistical graphics and average data when the simulator is off.

C. Portal traffic information service

With this service it is possible to obtain all relevant data from the vehicle and send it to a control center that will manage all the received information. All this data is compiled on a XML file and can contain average vehicle's variables, failures of the vehicle and also information about the gathered road by the user. Users, through the on board graphical interface can report these events to the traffic portal at the server.

The storage data on the XML file also includes information about Transport Protocol Experts Group (TPEG), so this information will be able to be sent to authorities, providing detailed traffic information about traffic jams, traffic accidents, weather conditions and so on. Included TPEG data also refers to the vehicle´s location, the road´s type and the kind of vehicle from which the information it is being sent.

Drivers could inform the control center about all incidents that they see on the road. This notification contains data like the GPS position of the accident point and the type of notification, in this case, traffic accident code. When the control center knows about the problem, it is easy to activate emergency services to aid people involved in the accident. . This service provides immediate notifications about all the possible problems that could occur at the road. It is also a good service for fleet management because it is possible to know the position of the different vehicles of the fleet are and its conditions.

In the eco-driving tag, the stored data is the average values of the main vehicle´s parameters like speed, rpm, CO_2 emissions or fuel level.

With the vehicle´s control maintenance tag, it is possible to send information about different components or systems of the vehicle that need to be controlled due to a possible failure. Then, the manage center is reported about possible future problems which could happen at the vehicle. So it will avoid the breakdowns and possible accidents in advance.

Finally, with the localization information, it will be possible

to know where each vehicle of the fleet is. Also it is possible to track the different routes that these vehicles take. So, fleet manager could have a rigorous control of the resources.

Now, we are working to develop this service on a communication platform based on IEEE 802.11p standard, as see in previous section. This on board communication system can work as a communications gateway and the application access could be reachable with a car-pc or a smart phone.

IV. DRIVING GUIDANCE SERVICE

These driving guidance systems are focused on providing drivers with real-time information related to the car's environment by performing a continuous image process together with other techniques.

The main purpose of the "Driving Guidance Service" (See Fig. 5) is to generate relevant information in order to help the users' driving and try to simplify it as much as possible. However, it is important to bear in mind that all these systems should always make driving easier without interfering the users' effort or attention. Thus, even though this service is just a prototype executed on a computer, it is regarded to be displayed through low cost common devices which can be afforded by almost every driver. So as to accomplish this goal, smart phones or video-cameras should be used. The selected device is placed on the car's dashboard and records everything in front of the car.
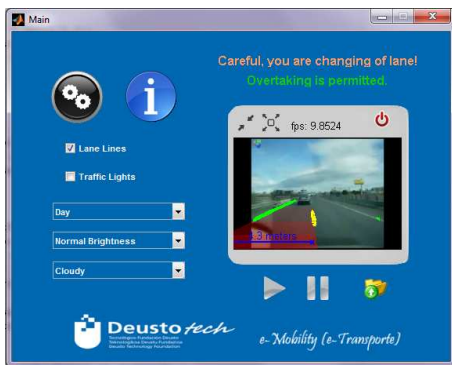

Figure 5. Driving Guidance Service Interface

The system described in this paper could work in the following way:
1) In the first place, the recorded video is divided into frames and each frame is processed individually.
2) Secondly, the frame is processed to adjust the image to some specific characteristics such as weather conditions, frame size...
3) Subsequently, the modified frame is analyzed to recognize and identify several issues involving road lanes detection, traffic lights detection, obstacles detection, traffic signs detection… The cardinal task of the system in question is carried out at this point.
4) Finally, once the previous tasks have been performed, the system makes use of the provided information and gives

the user some advice concerning the overtaking conditions, the recommended driving speed, the distance to the front vehicle and so on.

All these services rely on the fact that humans tend to lose their attention while executing the same activity for a long time [8], [9], [10]. So, according to this, what the users expect to receive are warnings when an unexpected event occurs (e.g. one car stops all of a sudden, the user is changing of lane…).

Nevertheless, this is insufficient. Not only the user needs to know that an unforeseen act is taking place, but he/she needs to know if it is possible to perform one action or not (e.g. know the maximum driving speed permitted at a road section, know whether it is possible to overtake or not…).

Due to the fact that the application needs to work under any circumstance with a high accuracy average, image color is not discarded. In fact, it is used to get the traffic lights' color to identify its state or to determinate the color of the road lanes among other situations. More specifically, in order to manage the color value, the RGB (Red, Green, Blue) model is used rather than CMYK (Cyan, Magenta, Yellow, blacK) or HSB (Hue, Saturation, Value).

Besides, even though the system processes each frame separately, successive frames are compared and analyzed together in some situations to identify relations concerning an object position or to discard false positives. Hence, the system accuracy is higher and performance increases considerably.

Compiling the total previous characteristics, we decide to take advantage of MATLAB products to develop this service. MATLAB, apart from being one of the best languages of technical computing, fits perfectly the system requirements [14], [15]. More precisely, all the algorithms utilize the "Image Processing Toolbox" which provides the user with many functions that significantly simplify the image analysis [11][12][13].

The core of the application relies on following features which can be easily executed in the user interface (Figure 5):
- Road lanes detection.
- Road lanes change detection.
- Traffic lights detection.
- Traffic signs detection.
- Obstacles detection.

The 'road lane detection' algorithm seeks straight shapes which are almost horizontal, so every circle or every vertical line is dropped. Additionally, each shape must have a minimum and a maximum amount of pixels inside of it. Finally, to consider those shapes as valid, they must intersect in a point round the middle of the image.

The 'road lanes change detection' algorithm is based on the previous one and it analyzes the position of both lines. If one of them is situated in the middle for more than a several amount of frames, it determines that the user is changing of lane.

The 'traffic lights detection' algorithm works the opposite. It searches for round shapes (circles) of a specific size.

Furthermore, it checks in case the color of the circle differs from red, orange or yellow; if so, circles are disposed. Accordingly, the state of the traffic light can be identified (Figure 6). Concerning to the 'traffic signs detection' algorithm, the system does not recognize each symbol or word. Instead of that, it crops the traffic sign from the image and visualizes it on the system´s user interface as it was recorded. Finally, the 'obstacle detection' algorithm checks whether a closed shape exists between the road lanes or not. If a closed figure is found, the color is analyzed to determine if its color differs from the color of the rest of the lane. The purpose is to alert drivers that something unusual is on the road.

All these steps provide the user with great advantages. Once the algorithms have been carried out satisfactorily, the system processes the information obtained and displays guidelines in that specific situation, recommending the user what it should be done to accomplish the ideal goal.

In a nutshell, the "Driving Guidance Service" does not replace the users' responsibility and must not be regarded as an application that guarantees the user safety; it is merely a user supplement which facilitates his/her labor.
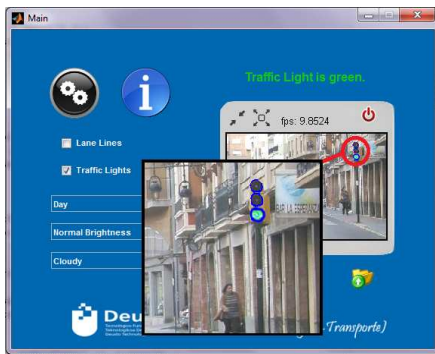

Figure 6. Driving Guidance Service Interface

V. CONCLUSIONS AND FUTURE WORK

As a conclusion to the presented work-in-progress we can say that there is still much work to be done in the field of driver assistance services. We must continue to improve the functionality and features of vehicular communications based on IEEE 802.11p. Then, once this communication system is stable, we could begin to deploy security and infotainment services as we have described in this paper, using this network infrastructure. Meanwhile, we can develop services that can be deployed in common terminals such as smart phones or tablets, gadgets independent from the vehicle and that could work as applications concentrators everywhere.

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