A Smart Drive to Future Transport Systems

R.Marrero-Almonte[1], E.Marín-Tordera[1], X.Masip-Bruin[1], R.Nuez-Baldoma[2], J.Batlle-Ferrer[3] , G. Ren[4]
[1]Advanced Network Architectures Lab (CRAAX), Universitat Politècnica de Catalunya (UPC), Spain
[2]Lear Corporation, Electrical Power Management Systems, Spain
[3]Doxa Innova & Smart, Barcelona, Spain
[4]IBM Almaden Research Center, San Jose, California, USA
{rmarrero, eva, xmasip}@ac.upc.edu, rnuezbaldoma@lear.com, jbatlle@doxais.com, gren@us.ibm.com

Abstract— **Road transport vehicles (RTV) technologies, features and capacities are rapidly evolving, hence fostering innovative transport paradigms strongly impacting on all involved transport players. Current and unforeseen technological advances are pushing for creating a novel environment where road transport users can be empowered with tools enabling higher flexibility, bringing new opportunities, opening social ecosystem participation and finally endowing the ability to determine which options are more feasible while traveling. However, the development of such environment is not so easy to deploy. Indeed, Intelligent Transport System (ITS) infrastructures should be improved to support the integration of heterogeneous technologies as well as to promote the development of ITS standards and smart transport vehicles utilization. This paper conceptually introduces the characteristics of an innovative hierarchical cloud-based architecture for an in-vehicular platform that integrates heterogeneous technologies, providing the necessary features to manage the connectivity, data, applications and services for RTV, thus providing them with analytic and smart "social"-oriented capabilities.**

Keywords- Road Transport Vehicles, Intelligent Transport Systems (ITS), cloud computing, social-oriented, data analysis, architecture for controlling and managing social-oriented ITS.

I. INTRODUCTION AND MOTIVATION

Demographic transitions, the environmental issues experienced by our societies as well as the technology evolution, are all driving the future of transport systems, thus fueling new smart transport paradigms, where the pure transportation function itself is extended and enriched with new challenging smart "social"-oriented capabilities. In fact, transport systems that, even today, are mostly devoted to transporting passengers and goods from one place to another, are envisioned as the perfect "*device*" to host enriched functionalities, leveraging data collected from their ecosystem (i.e., vehicles, users and context data), that may provide solutions to actual transportation problems (e.g., traffic jams, crashes, safety, etc.), but also may foster the development of novel "*smart functionalities"* for vehicles' users, with a high societal impact. This challenging scenario is completely changing the automotive industry in the process -which appears to be on the initial stages of a revolutionary change-, with the possibility to transform the way users interact with vehicles and undoubtedly reshaping the future of our roads and cities (i.e., the context).

Simultaneously, there is an undeniable trend today in city leaders positioning the continuous evolution of their current transport needs towards a much more demanding scenario. This evolution requires significant efforts to be devoted on correctly tracking the real needs (transport, users, and context) to be then efficiently mapped into valid and attractive benefits for citizens. Indeed, cities are passively seeing how new communication technologies (e.g. Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I) and Vehicle to Person (V2P)), are key elements pushing for the development of an efficient and reliable Intelligent Transport System (ITS) environment, where the different transport actors (users, vehicles and infrastructures) may interact each other. These communication technologies, while facilitating connectivity, are also producing an unstoppable growth of data, collected from different and heterogeneous ITS sources (i.e. smart cities, smart roads and smart vehicles). This capacity to get data along with the easy and broad connectivity is paving the way to endow end-users with innovative useful applications and services, thus driving and promoting a new role for users, who are acting as consumers but also as producers as well.

Additionally, the need to foster and maintain what is called social connectivity has become a major trend in nowadays society. In fact, today, the overall society relies on the implementation of existing and new technologies to maintain and enrich our social experiences, developing devices, services and applications that can facilitate and enhance such experiences. In this context, smartphones are currently the most used device for social interaction, although there was a time when phones were anything but smart, serving just one purpose: communicate (voice) with other people. It has been a long way in which these devices have gone through several technological transitions that were – and still are - enriching their capabilities. As a result, the term smartphones has become a familiar topic referring to devices that improve our ability to communicate (data), access and produce information through the integration of a variety of sensors (e.g., Accelerometer, Gyroscope, GPS and proximity), applications and services that provide several useful functionalities.

We have already noticed that humanity insatiable curiosity, people current needs and the overwhelming pace of innovation, are all leading the way through the transitions that can turn Road Transport Vehicles (RTV) into intelligent vehicles, which – similar to smartphones – are being equipped with sensors and technologies (e.g., On-board sensors, HUD, V2V and V2I Communications) that can confer them new smart "social"-oriented capabilities.

With this overall picture in mind, we envision a scenario where RTV must be considered not for what they were or currently are, but for everything they have the potential to be, offering applications and services to stakeholders and even share them with other devices, as well as harvest, process and distribute valuable and trustworthy information, either locally or remotely through any decoupled infrastructure (for example, the cloud). For instance, we envisage an scenario where: i) every vehicle can be equipped with the necessary infrastructure and connectivity to become a “local cloud”, providing resources that can benefit both other entities (e.g., other vehicles or pedestrians), as well as themselves (i.e. through data processing and storage capabilities), and; ii) the offered connectivity and availability of resources can be enhanced by enabling the access to other resources through external clouds, with a more robust performance, scalability and security, thus creating a hierarchical cloud architecture with a particular cloud computing deployment model (either Public, Private or Hybrid).

All the aforementioned capabilities must be properly designed and implemented, and most importantly, suitably and efficiently managed, thus demanding an entity responsible for such a “management plane". Unfortunately, nowadays RTVs lack of an entity that can handle and integrate the foreseen management demands, what may definitely hinder the deployment and adoption of the envisioned smart scenario. Furthermore, there are other constraints strongly affecting its deployment. On one hand, cities must improve their infrastructures to support the wide expected variety of technologies. This refers to not only allocating budget for communication devices deployment, but also to creating new regulations and policies aiming to promote smart transport vehicles utilization, as well as boosting particular services development, for example within local incubators. On the other hand, today’s vehicles user-oriented services are mostly centered on proprietary infotainment systems, focused on multimedia services, vehicle performance monitoring, as well as GPS-based applications and nomadic devices. This market of factory-fitted proprietary platforms is dominated by both Vehicle Manufacturers (OEMs) and their suppliers [1]. It seems obvious that this model is not going to scale for long (i.e., due to the long and not updatable life-cycles of the applications and services they provide). In fact, new RTV capabilities (e.g., interoperability and availability of resources from multiple vehicles, devices and also infrastructures) will push for a complete change in users’ behavior and their expected benefits, thus promoting new business models to come up, involving ISPs, cloud and service providers, as well as OEMs and software developers.

Therefore, the overall scenario (putting together data, communications, transport systems and the capacity for users to play a different role while accommodated in a vehicle), paves the way to new transport paradigms raising several research challenges, ranging from technology deployment to innovative business models implementation.

However, in order to accomplish a full deployment, a smart approach is required in every step of the life cycle (analysis, design, development, and implementation). Such approach must be mainly focused on user needs, standards, safety and integration issues, as well as the institutional and political barriers that may arise.

In this paper we introduce the main concept and characteristics of an innovative hierarchical cloud-based architecture for an in-vehicular platform characterized by: i) heterogeneous technologies integration; ii) provisioning RTV with the necessary capabilities to manage connectivity, data, applications and services, and; iii) provisioning RTV with analytic and smart “social”-oriented capabilities. This paper aims to craft the preliminary ideas of an innovative concept for the aforementioned management demands, which will be used to lead the creation of the forthcoming technical contributions to reach out to the full architecture design.

This paper is organized as follows: Section II presents the forthcoming technologies and the current available technologies to be incorporated inside RTV in order to provide the aforementioned capabilities. Section III offers a summary review of the proposed cloud-based architecture for RTV. Then, Section IV presents two illustrative use-case scenarios describing both how a smart vehicle might respond to a detected accident and how different ITS entities might “socially” interact. Finally, section V concludes the paper.

II. Present and Forthcoming Technologies: A Seamless Integration

Transport systems belong to a constantly changing environment, where all involved players must find solutions with the aim of both maximizing transport efficiency and capacities, as well as providing security and privacy for road transport users. For example, aligned to the technological progress and the envisioned future, city leaders may consider the creation of urban environments which can easily incorporate new technologies, thus offering great benefits to citizens, such as high connectivity (wifi communities), availability of information (open data) and easy interaction with other users and their surroundings (services repository).

Within these boundaries, road transport users must be empowered with applications and services that enable higher flexibility, opportunities to take action as well as immediate and reliable decision-making processing. These characteristics can lead to the creation of a suitable ecosystem – a novel smart transport paradigm - with smart “social”-oriented capabilities, nowadays absent within current RTV.

This innovative smart transport paradigm, that allows a seamless interaction between vehicles and users along with the ITS infrastructure, may be deployed through the integration of current and forthcoming heterogeneous technologies (i.e. V2I, V2V Communication, On-board sensors, Cloud Computing and Business Intelligence to name a few), leading to an environment where road transport users can freely access a wide range of regulated applications and services (e.g., Infotainment, navigation systems and toll services), from a variety of service providers and seamlessly interact with them, agnostically to vehicle brands or models.

From a software development perspective, the RTV environment can be divided into 2 sectors:

- The **OEM** sector that can continue to improve and develop new “under the hood” solutions (e.g. car performance, remote diagnostics, road data collection, driver assistance and communication). These solutions can be mandatory and regulated for their corresponding brands.

- The "front end" certified **developers and service providers** sector that can satisfy users' requirements –with more personalized solutions–, developing regulated and optional applications and services (entertainment, traffic information, navigation, fleet management, interactive and social applications) that can become rapidly ubiquitous. However, the diversification of this environment can produce interoperability issues that need to be carefully handled through active efforts on standards bodies.

Moreover, several recommendations are presented in [1] for a user-vehicle-infrastructure integration. Some of them are:

- Encouraging the development of standards for both in-vehicle communications and in-vehicle services.
- Considering a service model for regulatory applications.
- Creating a supportive environment without any legal, infrastructural, or institutional obstacles for the industry.

The aforementioned integration can provide a new ecosystem of business models that will benefit a large variety of sectors (e.g. OEM, ITS facilities or vehicle insurance companies). For example, road transport users will be able to satisfy their requirements through subscriptions, "pay as you go" and advertising business models – to name a few options.

In order to provide a clear perspective of the aforementioned smart transport paradigm, we have established a list of tentative current and forthcoming technologies that might be implemented within RTV for the deployment of such smart scenario. These technologies are introduced next:

- **V2V and V2I communications**. This technology is expected to become mandatory –initially in the U.S.– by 2022, as announced by the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) [2]. There is no doubt this initiative will be also adopted by other countries in the near future. This technology can greatly improve RTV capabilities, easing the accessibility to data produced by on-board sensors, nearby vehicles and infrastructures and other available data sources.
- **Long Term Evolution (LTE) wireless** technology is expected to come in upcoming models, providing customers with faster in-car connectivity and thus clearly benefiting user-vehicle integration. In fact, vehicle manufacturers know LTE's share of connections are increasing rapidly and are expected to be almost 30 percent by 2018, and 70 percent by 2022 [3], turning LTE into the most suitable option for in-car connectivity.
- **Cloud Computing** has the potential to become an extremely helpful instrument when it comes to process and store information from different entities that collaborate in the ITS ecosystem (e.g., Smart Cities, Smart Roads and RTV) [4]. This technology is able to provide benefits through 3 different service models: Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS).
- **Advanced Driver Assistance Systems (ADAS)** [5] is a clear example of the deployment of on-board sensor technologies that directly benefit vehicular environments, including: Electronic stability controls, Smart Headlights, Adaptive cruise control, Forward collision and Blind-spot warnings – to name a few.
- **Digital Mapping and Global Positioning Systems (GPS)** are one of the most helpful tools ever developed for transport systems. They provide sophisticated representations (virtual images) of our environment through the collection of vast amounts of information and the provision of highly precise location references respectively, potentially offering a great deal of benefits for RTV environments and encouraging the development of innovative applications and services.
- **Speech Recognition**. Advances in this technology are providing drivers with safer ways (i.e., spoken words) to manipulate an increasing number of in-vehicular functions (e.g., play music and search locations), thus dissipating any relevant distractions.
- **Head-Up Display (HUD).** This technology has experienced a wide interest on vehicle manufacturers, since it allows drivers to visualize information through the windshield, closer to the normal field of view and decreasing the possibilities of distractions.
- **Business Intelligence** provides methodologies and capabilities that transform raw data into meaningful and useful information, therefore providing better decision-making support within the ITS ecosystem, with comprehensive reporting and monitoring capabilities. For instance, through gathering and processing raw data from the vehicle's on-board sensors, drivers can have access to several reports related to the performance of different aspects of their vehicles.

Some of these technologies have been feeding RTV for several years (i.e. GPS, Digital Mapping). Others are starting to be deployed (i.e. Speech Recognition, Head-Up Display, LTE), and are expected to produce excellent results. In the meanwhile, V2V, V2I communications are being tested in order to meet RTV requirements. Remaining technologies (namely cloud computing and Business Intelligence) still require some way to go, due to their dependency on other technologies (e.g., connectivity is required for cloud computing and data processing capabilities have to be carefully tested and integrated for Business Intelligence).

In general, the adoption and deployment of this set of technologies will bring both many relevant challenges in the ITS area (for instance, privacy, security or standardization), and a staggering benefit impacting the ITS sector, but also many other aspects of our lives.

III. The Proposed Architecture

RTV technologies have undergone a sea change over the years. Starting as fully mechanical to become electro-mechanical transportation systems with a wide variety of sensors to control themselves (e.g., electronic ignition or climate and emissions). These sensors actually produce an overwhelming amount of data, which currently is not being wisely used by vehicle's users or vehicle manufacturers. All the in-vehicle sensors collected data, along with the external data provided by smart cities and smart roads (e.g., infrastructure and road sensors) will provide a great deal of social benefits [6] and will be available for alternative usage.

The set of capacities consisting in unstructured data, connectivity, as well as OEMs and developed applications and services produced for and by RTV, requires a management in-vehicular entity responsible for suitably processing them. This in-vehicular entity will integrate the set of capacities and the heterogeneous technologies (e.g., HUD, Business Intelligence and Cloud computing), distributing the produced outcome with the aim of providing relevant content for the ITS entities (e.g., RTV users, ITS facilities and OEMs).

Considering the lack of such entity, we present the main concepts and characteristics of an innovative cloud-based architecture (see Fig.1) for an in-vehicular platform, which integrates heterogeneous technologies (e.g., cloud computing, Business Intelligence, V2V and V2I Communications), providing the necessary capabilities to manage connectivity, data, applications and services for RTV, providing them with analytic and smart "social"-oriented capabilities.

The proposed cloud-based architecture, provides functionalities that extend the RTV capabilities supported and empowered by a hierarchical cloud service model as shown in Fig. 2. The architecture introduces the concept of local cloud as the set of "physical" capacities (so far processing and storage) implicitly allocated within the vehicle, required to process (un-) structured data as well as to store and distribute relevant information for stakeholders. This scheme facilitates fast and more secure reaction to those applications and services running in the vehicle.

Furthermore, local cloud capacities may be extended towards a hierarchical cloud architecture. In fact, the involved entities (OEMs, developers, service providers and vehicle users) can take advantage of the benefits inherent to using an external (outside the vehicle) cloud (i.e. which can be private or public depending on the characteristics of the applications, services and information to be managed). These benefits may refer, so far, to: i) additional processing and storage capabilities; ii) novel control and management functions, and; iii) aggregation or clustering capacities; all being capable of processing and analyzing information not from a single vehicle, but for many vehicles, thus endowing applications and services with more accurate information. Some of the expected functionalities provided by the deployment of this architecture are listed below:

- **Integration of flexible communication methods.** The integration of LTE, V2V and V2I communications are strictly necessary in order to provide connectivity between vehicles, infrastructure and people's devices.
- **Interoperability between other systems**, such as ADAS and interaction technologies (e.g., HUD) facilitating the provision of relevant information to the users (e.g., Blind Spot Warnings or Forward Collision Warnings).

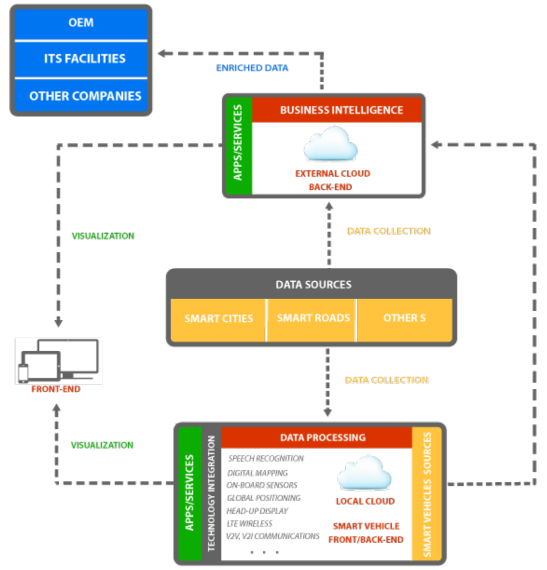

Fig. 1. Cloud-based Architecture for road transport vehicles

- **The capacity to gather, process, store and share information in an acceptable amount of time.** Storage and efficient processing capabilities along with an architecture that can integrate data processing technologies, (e.g., Big Data and Business Intelligence) seamlessly within the vehicle and through the cloud need to be provided.
- **Security, integrity and privacy mechanisms** must be in place, in order to protect the user's information (e.g., authentication and encryption methods). With the capacity to appoint certain information as restricted when required.
- **Allow application updates from OEMs and certified developers, as well as service management for authorized users**. Actual in-vehicular applications have the disadvantage of requiring life-cycles which are often aligned with vehicle life-cycles. OEMs and developers will incorporate their corresponding in-vehicular applications that will be regularly updated.

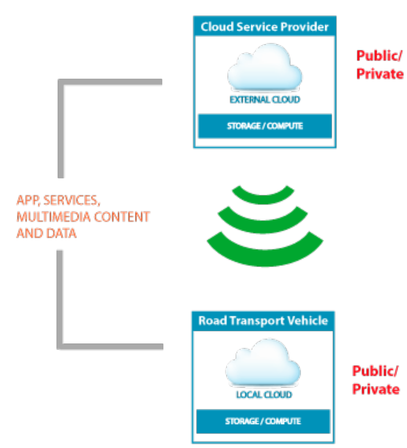

Fig. 2. Hierarchical cloud for RTV

- **Provision of entertainment, social and navigation capabilities**, in order to decrease the actual dependency of nomadic devices.
- **Use of an adequate cloud service model (IaaS, PaaS, SaaS)** that will provide a cost effective and efficient infrastructure, platform or software. This will help to meet the demand of the overwhelming amount of data and storage capacity, with consumers able to provision storage, network and other resources.
- **Accessibility.** Front-end devices (e.g., smartphones, tablets, PCs) have to be able to access applications and services from the vehicle, as well as through the cloud, depending on the user's location. OEMs, ITS facilities and other stakeholders have to be able to use the external cloud services in order to receive relevant information (e.g., vehicles performance, traffic status, road status, etc.).
- **Methodologies that allow data collection technologies to work with personal data (e.g., locations and time stamps related to a specific individual) without rising privacy issues.** We need to consider relevant methods to clearly identify the collected, stored and associated data, as well as to identify ownership rights and who can access the data produced.
- **Procedures and standards related to publishing and accessing public road data**. A proper definition of the roles played by the different entities for data exchange cooperation is necessary, in order to provide reliable multimodal information and services.
- **A business architecture that can satisfy the private and public sector.** For instance, requirements for digital tacographs and freight transport are different from the requirements of private transport, which are mainly focus on providing value added services through infotainment.

IV. Illustrative Examples

For the sake of overall understanding, we introduce 2 examples to illustrate some of the expected functionalities and benefits inferred from the proposed platform.

A) 1st Use case

This first use case scenario, drawn in Fig.3, describes how a smart "school bus" responds to a detected accident up ahead, and how different entities provide a social interaction.

Actors

School bus, bus driver "Rick", bus passenger "John", private car, private car driver "Ana" and School.

Preconditions

Both vehicles (school bus and private car) use a platform implementing the characteristics of our architecture. John's tablet has the required applications and services to interact with smart vehicles (school bus and private car). The School and the private car have permissions to receive notifications from the school bus.

Basic Flow of Events

The following events represent the set of actions triggered within the proposed use case.

1. The use case begins when Rick and Ana starts driving.

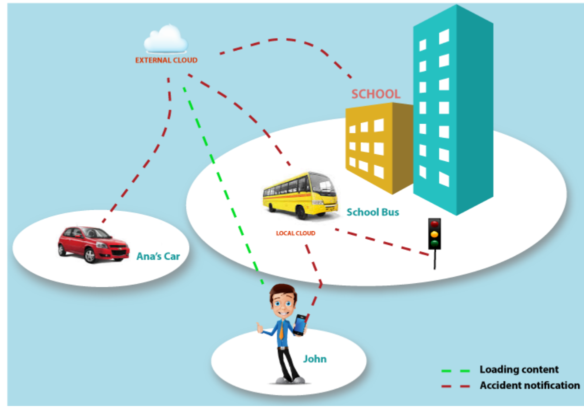

Fig. 3. 1st Illustrative example

2. An accident occurs in the route Rick takes to complete his journey.
3. The nearest traffic light informs the school bus about the accident.
4. The school bus notifies Rick about the accident and asks about changing routes offering the most suitable routes, depending on fuel level, weather and traffic.
5. Rick selects one of the options best suiting his needs.
6. The school bus informs the School about the accident and the new route selected by Rick.
7. The school bus informs John about the accident, the route change of the school bus and the estimated time to reach home through his tablet.
8. The school bus notifies Ana's car about the accident and the route change.
9. The car informs Ana –John's mother- about the accident, the route change of the school bus where John is and the estimated time John will take to get home.
10. John uploads his homework to an external cloud -using his tablet-. His homework is now accessible from Ana's car, in order to finish it when they leave on a trip this afternoon.

It is highly evident that some of the actions included in the flow of events (e.g., school bus sending notifications, car sending warnings) cannot be adequately processed unless a hierarchical cloud management strategy is defined.

B) 2nd Use Case

RTVs are equipped with different useful systems (e.g., collision avoidance systems) to provide assistance during critical situations. These systems are able to detect imminent crashes, warning the driver and also providing autonomous actions if required (e.g. call for assistance). However, pedestrians are not equipped with any useful systems that can warn them, neither helps them obtain assistance in a critical situation –considering they are not able to use any mobile device during the situation-. In this use case scenario, see Fig.4, we describe how a pedestrian can obtain assistance –via our hierarchical architecture- after an accident with a faster and precise response by the corresponding entities (e.g. Ambulance), we also present cooperative actions of a private vehicle and the ITS infrastructure in order to provide the required information of the incident.

Fig. 4. 2nd Illustrative example

Actors

Pedestrian “Mark”, Ambulance, Private car, Private Car Driver “Brian”, ITS infrastructure “Traffic Lights”.

Preconditions

The private car and ITS infrastructure use a platform implementing the characteristics of our architecture.

Basic Flow of Events

The following events represent the set of actions triggered within the proposed use case.

1. The use case begins when Mark has a cardiac arrest crossing through an intersection.
2. Brian is witnessing the incident and selects assistance from his vehicle, providing the type of incident and his exact location to the nearest Hospital.
3. The nearest traffic light is notified of the incident and informs the surrounding vehicles as well as other traffic lights about the incident in order to ease and control the traffic of the corresponding intersections.
4. The Hospital receives a notification of the incident with the type of incident and the estimated time to arrive to the respective location.
5. The Hospital first selects the type of Ambulance to be sent (equipment required to handle patient’s emergency), and then it sends the selected Ambulance unit to the respective location.
6. The Ambulance follows the corresponding intersections previously assigned by the traffic lights, optimizing time response for medical assistance.

Same as use case 1, some actions in the flow of events, such as the interaction with the traffic lights, are requiring resources management and control capacities not yet defined.

In summary, building the proposed cloud-based architecture and defining its correct management and control strategies, would enable a new set of added-value services and apps, substantially improving the overall ITS performance.

V. Conclusions and Future Work

Leading edge technologies are essential for an efficient and sustainable ITS ecosystem capable of providing a smart social environment, where all involved ITS entities can share content and relevant information seamlessly. In this paper, we introduce the concepts and main characteristics of an innovative cloud-based architecture for an in-vehicular platform that integrates heterogeneous technologies. We have considered analytics, social oriented capabilities and ubiquitous connectivity as the main aspects of this architecture, in order to face the constant evolution of a demanding ITS scenario. We have established that the combination of current and forthcoming technologies (e.g., V2I and V2V Communications, On-Board Sensors and Speech Recognition) will lead to the development of an efficient RTV platform. However, we recognized that the deployment of a platform with these characteristics represent several important challenges. For instance: i) ITS Infrastructures and RTV should be improved to support the heterogeneous technologies; ii) the development of ITS standards for more interoperability should be promoted, and; research efforts must be devoted to manage the proposed hierarchical architecture.

In short, the architecture presented in this paper introduces a first conceptual approach to deal with the integration of demanded control and managing requirements, to provide users (also including the industrial sector) with a new set of applications, services and functionalities, built on top of innovative business models. The architecture leverages state-of-the-art technologies while also building on top of new solutions, featuring scalability, accessibility, user’s adaptability, openness, privacy and safety challenges that need to be carefully considered on further research activities.

Next steps for paper’s authors are first to develop the strategies and policies required to manage the proposed architecture and second to test and validate the proposed mechanisms on real cloud and transport infrastructures.

Acknowledgment

UPC authors acknowledge the support received by the Spanish Ministry of Economy under contract TEC2012-34682 (project partially funded by FEDER), and the Catalan Research Council under contract 2014 SGR 371.

References

[1] Adoption of an open in-vehicle platform architecture for the provision of ITS services and applications. http://ec.europa.eu/transport/themes/its/road/action_plan/open_in-vehicle_platform_en.htm. (Retrieve on January 2014).

[2] Connected Vehicle Technology Industry Delphy Study. http://www.michigan.gov/documents/mdot/09-27-2012_Connected_Vehicle_Technology_-_Industry_Delphi_Study_401329_7.pdf (Retrieve on Febraury 2014).

[3] Advancing LTE migration heralds massive change in global M2M modules markets. https://machinaresearch.com/ news/press-release-advancing-lte-migration-heralds-massive-change-in-global-m2m-modules-markets/ (Retrieve on Febraury 2014).

[4] Z. Khan, S.L. Kiani. “A Cloud-based Architecture for Citizen Services in Smart Cities”. IEEE International Conference on Utility and Cloud Computing. 2012.

[5] European large-scale field operational tests on in-vehicle systems. EuroFOT. http://www.eurofot-ip.eu/en/library/deliverables/sp1_d113_final_report.htm. (Retrieve on January 2014).

[6] R. Wallace, K.Hill, B. Smith. “Green and connected”. Department of Transportation. Center for Automotive Research. September 28, 2011.