M:VIA, SMARTER VEHICLES AND ROADS BY USING NEW GENERATION ITS CONCEPTS AND IMS CAPABILITIES

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ABSTRACT

The m:Vía system combines advanced concepts of Intelligent Transport Systems and Services (ITS) with the capabilities of the IP Multimedia Subsystem (IMS) to offer enhanced communications and services in vehicular environments and to hide the complexity of offering value-added services. In the vehicle, the m:Vía communication unit manages connectivity, and several user services have been implemented in the m:Vía application unit. Services make use of IMS capabilities, through an IMS client embedded in the application unit. On the road, Road Side Units offer information and extra connectivity to Internet. Results showing the advantages of the proposed system are expected from ongoing field tests.

KEYWORDS

Intelligent Transport Systems, IMS, OSGi, VANET

I. INTRODUCTION

The use of Information and Communication Technologies (ICT) in the transport sector promises to boost a major breakthrough in road safety and traffic management, as well as to provide advanced information and entertainment to the driver and the passengers, and even to allow cleaner transportation. These and other goals in transport and traffic management are addressed by Intelligent Transport Systems and Services (ITS).

Much research work has been carried out, or is currently ongoing, aiming to solve some of the open issues or shortcomings of ITS, such as network protocols for cooperative vehicular communications or architectures for provisioning of services in vehicular scenarios. Some of the most remarkable research projects in Europe are CVIS, SAFESPOT, COOPERS or COMeSafety [1]. Several groups are also working in standardization, such as the ETSI TC ITS, ISO TC 204 or IEEE802.11p. Despite the great effort already performed in the topic, there is significant work to be done for advanced ITS technology to be ready, adopted and widely deployed, being realistic implementations and field operational trials some of the key issues to be further realised.

Regarding communication networks, the IP multimedia subsystem (IMS) is a promising solution to merge the Internet world with the telecom operators world. As part of the advanced network solutions embraced under de concept of next-generation networks (NGN), IMS is being adopted by an ever increasing number of telecom operators. IMS makes it possible not only to provide access to all the Internet services through cellular networks, but also to offer network capabilities and functionalities to third parties, such as charging features, identification and authentication and messaging or conferencing. Although some of these features may also be offered by a third party with a service on the Internet, there are some clear advantages in using the capabilities offered by the operator: reliability, management of quality of service (QoS), trust and security, etc.

In spite of the clear interest of IMS and network capabilities in cases where Internet and mobile systems converge (such as information services offered to high mobility users in vehicles), its application to ITS and vehicular scenarios is still scarce. For example, [2] proposes an extension of the 3GPP IMS emergency service architecture to provide enhanced, context-aware emergency services, which could be adapted to emergency services in vehicular scenarios. In [3], a method to improve communication and security in VANET based on information managed through IMS is presented. On the other hand, the German CoCar project, which aims at research in V2V and V2I communications by using cellular systems, uses IMS in its vehicular communication solution. It is worth noting that, although CoCar considers IMS as an interesting solution to support advanced ITS applications and includes it as a future work, this use of IMS capabilities in services for ITS has not been addressed by CoCar yet [4]. In summary, related work of using IMS in the ITS context is focused on the use of IMS to improve vehicular communications, but little research shows the advantages of using IMS in terms of ITS services.

m:Vía is a Spanish research project that contributes to the progress of ITS mainly by **including enhanced IMS capabilities** in an advanced architecture for communications and services in ITS. This allows ITS applications to extend their services by using information or functionalities available in the core network of the telecom operator in a secure and reliable way. Furthermore, the m:Vía architecture mostly follows the European reference architecture for ITS [5], but it adds a novel **gateway functionality of Road Side Units** (RSUs), which allows the system to provide Internet access to users through the RSUs, and it also introduces the concept of **nomadic RSU** with WiMAX as backbone connectivity, which allows a straightforward deployment of RSUs.

The rest of the paper is organized as follows: in section II the general architecture of the m:Vía system is presented, its main modules explained and the selected HW for implementation mentioned. Section III is devoted to present the proposed solution to include IMS capabilities in ITS applications and usage examples are given. Also planned test scenarios are pointed out. Finally, in section IV the conclusions of the paper are drawn.

II. M:VIA GENERAL ARCHITECTURE AND IMPLEMENTATION

The general architecture devised by m:Vía project considers three main elements in the overall system: the vehicle, the intelligent road and the communication network infrastructure (see Figure 1). The vehicle is equipped with two different units: the Application Unit (AU) and the Car Gateway (CG, also called Mobile Router or On-board Unit for Communications). The former one provides an open platform for services and applications to be deployed and managed in the vehicular environment, while the latter one is in charge of communications with other vehicles, elements in the roads and Internet. Both on-board units are directly interconnected through Ethernet.

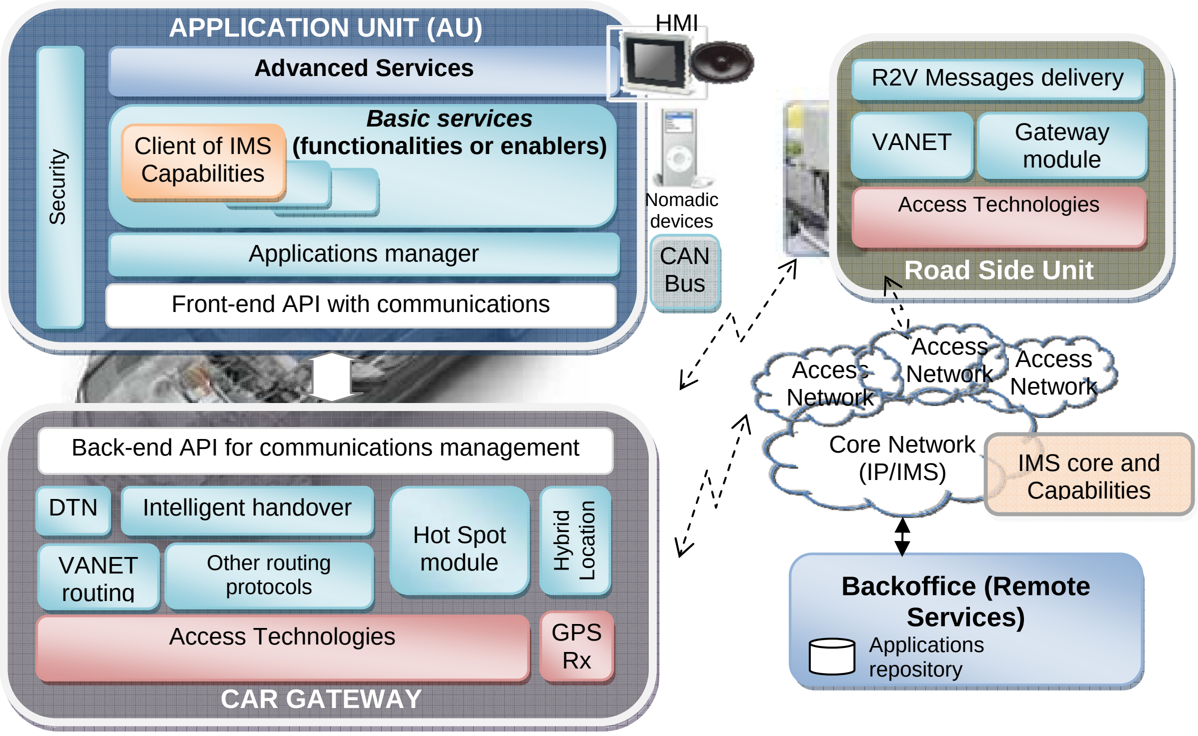

Figure 1. General m:Vía architecture

Intelligent roads are equipped with Road Side Units (RSUs, see Figure 1), which offer both communication capabilities and collection/delivery of information of interest (e.g. traffic parameters, road incidents, warning messages…). Remote information, services and capabilities are also available through the network infrastructure. IMS core and capabilities are also included. More details on the implemented modules are given in next subsections.

m:Vía approach for ITS communications

m:Vía fulfils the communications requirements of ITS services by adopting a hybrid approach. No single access technology is capable of satisfying so diverse requirements as fast dissemination, global coverage, delivery guarantee, delay tolerance (or bounded latency) or high throughput. For this reason, m:Vía combines three access technologies (UMTS, WiMAX mobile and WiFi), which are managed by the modules depicted in the Car Gateway and Road Side Unit boxes in Figure 1. Except the Gateway module, the CG and RSU modules depicted in Figure 1 can be mapped to the European ITS Station Reference Architecture [5].

From top to bottom, in the CG we find the *API interface* module between the CG and the AU, which offers communication features to the ITS services. This API consists of a front-end (AU) and a back-end (CG) and is CALM-compliant [5]; that is, any CALM-compliant service can use the m:Vía communication system. The *Intelligent handover* module is core to the hybrid approach and consists of two m:Vía-proprietary elements: the smart client and the roaming platform. The former monitors the connectivity of the access technologies to identify whether a vertical handover is needed, while the latter routes the data from the ITS services depending on the QoS requirements and dynamic link availability of the access technologies.
The *Delay-Tolerant Network* (DTN) module maintains the sessions in the event of connectivity disruptions, which typically occur in ad-hoc networks. This is achieved with two

proxies (CG and Internet) that maintain the sessions even when there is no connectivity in any of the three access technologies available in m:Vía. The *VANET* module provides vehicular ad-hoc networking capabilities for communications with vehicles and RSUs and consists in Ad hoc On-Demand Distance Vector (AODV) routing. UMTS and WiMAX routing capabilities are included in the *Other routing protocols* module in Figure 1. The *Hot Spot* module provides intra-vehicular connectivity so that WiFi-enabled nomadic devices, e.g, laptops or PDAs, can access the Internet via the CG. This module includes DTN support and user authentication for access control. Finally, the *Hybrid Location* module provides enhanced positioning for navigation-related services. It calculates the position of the vehicle by triangulating with WiFi access points (with radio beacons) in areas with no GPS coverage. When the GPS signal is available (GPS Rx module in Figure 1), the Hybrid Location module selects the best location accuracy between the WiFi and GPS location techniques in a seamless way.

In the RSU (Figure 1), the *VANET* module is that of the CG. The *R2V Message Delivery* allows backoffice ITS services to broadcast a message within a specific geographical region. This functionality obtains the message and the configuration parameters (frequency, duration, and the coordinates of the area) from a remote server and, using the *VANET* module, broadcasts the message to every vehicle within the defined region. Finally, the *Gateway* module connects the RSU to Internet, for two different purposes: allowing the backoffice (Figure 1) to access the R2V Message Delivery module, and providing Internet access to vehicles without mobile broadband connectivity. Note that the RSU does not manage vertical handovers; WiFi is the access technology to communicate with vehicles (VANET), and WiMAX wirelessly connects the RSU with the network infrastructure.

In terms of implementation, the CG runs over specific hardware designed for on-board use with the following specifications; Alix 2c2 PC Engine, 500 MHz AMD Geode LX800 CPU, 256 MB DDR DRAM, 1 Gb CompactFlash for storage, 2 Ethernet LAN, 2 USB. The OS is TELefónica LINuX OS (TELINX) [7], a customized Open Embedded distribution for vehicular environments. The RSU has a similar implementation. Note that due to the commercial unavailability of IEEE 801.11p, VANET connectivity is provided by IEEE 802.11b WiFi. Note also that the m:Vía AU (Figure 1) is enabled with CAN-bus and Bluetooth in-vehicle connectivity capabilities. A *CAN Bus* custom module grants access to the vehicle electronic systems to provide information such as speed or fuel consumption to the ITS applications. The *Bluetooth* module is an off-the-shelf Bluetooth-USB dongle used by ITS applications to provide enhanced services to Bluetooth-enabled nomadic devices, e.g,, mobile phones.

m:Vía approach for ITS services and applications

On-board services and applications in the m:Vía system are deployed in the AU on top of a services execution platform based on the OSGi [8] standard framework. OSGi technology has also been adopted by other projects focused on ITS (e.g. CVIS), and provides a framework that reduces complexity of deployment and management of applications.

Several blocks constitute the AU software architecture, as depicted in Figure 1. High level services are grouped in the *experimental advanced services* block, while several basic functionalities comprise the *basic services* or *enablers* block. The *applications manager* module is in charge of controlling the installation and suitable performance of the on-board services. Moreover, it allows downloading new applications and updating versions from a remote web server. Security in the application layer is addressed by the *security module,* which controls authenticity of downloaded applications by using digital signature technology.

The experimental advanced services meet four user scenarios, and may be seen as examples of wide applicability of the m:Vía system. For each scenario, several services were implemented as representative ones:

- *Traffic Management*, with services such as access control to restricted zones, processing of sensors in the vehicle, and planning of routes and travel time. They assist the driver in avoiding jams or other traffic problems and they can also be used by traffic authorities in order to manage roads and urban transport.
- *Safety*, which includes services such as advanced emergency call and warning of incidents on the road. This type of services involves both vehicle users and third parties such as control centres and emergency bodies.
- *Professional Services*, covering services suitable for private transport companies. As example, taxi sharing and online trucks diagnostic have been implemented.
- *Infotainment* (information and entertainment), with services such as travel plan sharing, delivery of personalized alerts, and provision of multimedia information using nomadic and mobile devices. The target users are both passengers and driver.

The enablers or basic services are building blocks that provide specific functionalities to high-lever applications. The set of m:Vía on-board enablers are summarized in Table 1 (due to space constraints they are not explained in detail).

Table 1. Set of enablers implemented in m:Vía system

On-board enabler	Functionality
Authentication	Management of authentication to access services in the AU. Two available methods: login/password and authentication based on NFC (Near-Fear Communication). On-board authentication is extended with automatic remote authentication in IMS core and backend servers.
Human Machine Interface (HMI)	Multimodal HMI manager (graphical, vocal interfaces), designed for vehicular environment. It includes priority manager of messages.
Vehicle positioning	It offers position information to applications in the AU, by using location data from the Car Gateway.
Navigator	Provision of cartographic routes and geo-referenced POIs (Points Of Interest) to be used by high-level services.
Access to sensors	It provides in-vehicle sensors data (speed, revolutions per minute, error codes, etc) to the rest of services. ODB2 interface is used.
Warnings manager	It receives infotainment warnings (weather, news, etc.) and formats them to be shown on the HMI or on a nomadic device
Provision of services to nomadic devices	Detection, identification and content provisioning from the AU to the nomadic devices (PDAs, smart phones, laptops) through Bluetooth
Protocol utilities	It provides a suite of libraries to facilitate the use of commonly used communication protocols, like SIP, SOAP, etc
IMS Client	It enables authentication and access and to IMS core, and centralizes the use of IMS capabilities by on-board applications (see next section)

Regarding implementation, the AU runs over specific hardware with the following specifications; VIA EPIA CN Mini-ITX mainboard, 1.3GHz VIA C7 processor, 1 GB DDR2 RAM, 4 USB 2.0, 1 Ethernet LAN and several ports. The used OS is similar to the one used in the CG: TELefónica LINuX OS (TELINX) [7].

Apart from on-board modules, the m:Vía approach for services includes a remote *backoffice* module (see Figure 1), representing the servers that provide remote functionalities needed for offered services (e.g. server gathering and processing traffic data, Public Service Answering Point, etc).Also an applications repository has been implemented, enabling new applications or updates to be downloaded and installed in the AU.

III. ENRICHING ITS SERVICES WITH IMS CAPABILITIES

Proposed solution

The main novelty of the use of IMS proposed by m:Vía consists in the provision of capabilities from the network operator to enrich intelligent transport systems and services, by offering functionalities to both on-board and remote services and applications, as well as the adaptation of these capabilities to the vehicular environment. This way, ITS service developers can take advantage of existing features such as authentication, accounting, presence, user profiling, instant messaging…Since IMS interface with applications follows standards, a faster implementation and service deployment is possible.

In the m:Vía approach, a reference implementation of an IMS core has been deployed, consisting of the basic standard core modules. On top of this core, network capabilities are implemented and provided to third-party remote services. These capabilities can be accessed by either SIP protocol or other widely-used protocols (e.g. SOAP). Two well-known IMS capabilities have been implemented and integrated to show the possibilities of IMS in ITS world: presence and instant messaging, but many others are also possible, such as IP-based videoconferencing, identity management, location, etc.

An on-board IMS client has been implemented to centralize the access to IMS network, which complies with OSGi technology and follows SIP protocol. It provides IMS functionalities in the form of OSGi bundles to be consumed by on-board applications. Its main functionalities are user registration, instant messaging reception/transmission and management of presence events. User registration is synchronized with local registration, so the IMS user is automatically registered in the IMS core when the driver or passenger logs in the on-board system. Then, IMS capabilities are directly available for on-board services.

In order to validate the advantages of IMS capabilities, they have been integrated in two of the proposed ITS services:
· On-line truck diagnosis, which offers remote monitoring of the state of vehicles for professional use. The information about current state of the vehicle is continuously monitored by the on-board service, and published as a presence state (on route, breakdown,…) using the presence capability. This information is received by the remote service, which can then process it and even send commands or advices to the driver by means of the instant messaging capability. The use of IMS capabilities avoids the development of specific functionalities to publish the vehicle state and to exchange instant messages between control center and driver, even providing a network-agnostic solution.

· Access to restricted areas, which controls access of vehicles to restricted areas. For specific vehicles such as ambulances, the presence capability is used to inform about current state (e.g. idle or in emergency), so the access is automatically granted when there is an emergency situation. The presence capability has been enriched to include extra information of interest in the SIP message sent to update the presence state, by including location information when the vehicle is in emergency state. The modified capability complies with the corresponding standard. Thanks to this, a standardized solution to send information about the vehicle state is provided, which is of interest to achieve interoperability among multiple areas/cities with different access control solutions. Moreover, IMS provides a trustworthy vehicle authentication, thus making it more difficult to maliciously misuse the service.

Test scenarios and measurements

In order to evaluate the performance of the implemented m:Vía system, as well as to demonstrate the feasibility and advantages of using IMS capabilities in ITS services, a test plan has been designed. Two groups of tests have been included:

- *Performance evaluation of communication solutions*: it includes tests to quantitative evaluate the implemented solutions for communication needs (e.g. VANET performance, handover operation in different situations, etc.). Also the coexistence of multiple wireless technologies is experimentally analyzed.
- *Evaluation of services:* these tests aim to validate the implemented services at functional level, as well as showing the advantages of using IMS capabilities. Following the ISO 9646 standard, a list of conformance test cases was designed for testing each service, (details not included here for the sake of concision). Also user experience aspects are included.

Two test set-up has been carried out: bench test set-up and field testing set-up. For the first one (see **Figure 2**, left), a prototype of the m:Vía system has been mounted and tested in a semi anechoic chamber, where communication measurements have been performed and are being evaluated. Field testing is being carried out in the Technological Park of Andalusia, Spain, where two RSUs and a WiMAX Mobile base station have been deployed at AT4 wireless facilities (see **Figure 2**, right), and a car has been equipped with an m:Vía prototype. Measurements are ongoing. Expected results will contribute to a better knowledge on the effect of multi-radio technologies in vehicular scenarios, will provide quantitative data of the system performance and will show the feasibility and benefits of using IMS in ITS services.

Figure 2: Bench test set-up (left) and field testing area with RSU deployment (right)

IV. CONCLUSIONS

The m:Vía project is one of the biggest collaborative research efforts in Spain to demonstrate the technological feasibility of ITS communications to offer value-added services for drivers and passengers. With respect to standardization efforts in the field, m:Vía adopts the European ITS Station Reference Architecture and extends it with a Gateway functionality in the RSU. The m:Vía communications solution is also compliant with the ISO CALM architecture in the sense that any CALM-compliant ITS service can use the m:Vía Car Gateway. As a result, an easier integration of m:Vía solution with other implementations and frameworks that follow these reference approaches is possible. Besides extending the ITS Station Reference Architecture, m:Vía exploits the telecommunications operator capabilities in the vehicular environment. That is, the on-board service framework is enabled with an IMS client so that ITS services can be easily enhanced using standardized access to IMS capabilities residing in the operator network infrastructure, such as presence or location, which are key to safety (e.g., remote diagnosis) and sustainability (e.g., access to restricted areas). With respect to service providers, IMS provides standard access to capabilities and user data, hiding the complexity of network and data management processes and standardizing much of the development and provisioning, which is valuable in the ITS field.

Future work encompasses the experimental validation of the performance of the m:Vía communications system, as well as the quantitative and qualitative demonstration of the advantages of using IMS in ITS services. The former will be done through both bench and field testing, while the latter will also involve user experience aspects.

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