IMS and Presence Service Integration on Intelligent Transportation Systems for Future Services

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Abstract. Once some stable solutions appear to be found at physical and network layers for cooperative Intelligent Transportation Systems (ITS), deploying vehicular services and managing their operation over a common framework is becoming a key issue. Apart from proprietary and ad-hoc solutions, this paper presents a platform based on the IP Multimedia Subsystem (IMS) for deploying ITS services. The proposed architecture decouples IMS from a specific communication technology, to provide a common framework where to deploy and access both peer-to-peer and infrastructure-oriented ITS services. IMS capabilities have been used as an overlay network to provide vehicular services. Standard features of IMS, such as authentication, authorization, accounting, instant messaging, and session or subscription management, are exploited as a common basis for ITS services. In particular, the work presented shows how the standardized IMS Presence Service can be extremely useful for services which follow a publish-subscribe scheme, very common in vehicle-to-infrastructure applications. The whole IMS-based platform has been both designed and developed, even presenting reference implementations of real services.

Keywords: Vehicular Services, IMS, NGN, SIP, ITS.

1 Introduction

According to [1], vehicle telematics can be defined as "the use of computers and telecommunications to enhance the functionality, productivity and security of both vehicles and drivers". Vehicular networks are becoming essential for telematics services within the Intelligent Transportation Systems (ITS) field. Nowadays, there are more and more vehicular services which needs communications with both the surrounding vehicles and the infrastructure. The literature about ITS has many works about communication technologies used to connect vehicles with other vehicles and with local or remote infrastructure points, and multitude of works dealing with routing problems at network level. However, apart from physical, MAC and network routing issues, an ITS telematic platform needs a suitable framework to access, delivery and manage services oriented to drivers, occupants, road operators, administrations, etc.

In the above described scenario is where Next Generation Networks (NGN), and the solution given by the 3GPP, by means of the IP Multimedia Subsystem (IMS), are found useful to deploy ITS telematic services. IMS is a proposal standardized by 3GPP for the provision and deployment of multimedia services to final users, enabling the convergence of voice, video and real time data over IPv4 and IPv6. IMS works over the IP layer, and the technologies in which it relies, such as SIP (Session Initiation Protocol) [2] for session control, allow a fast development of services and reduces the operation and infrastructure costs. Furthermore, there are several standardized services within IMS specification, such as the Presence Service, location functions or Instant Messaging (IM). Among them, the Presence Service provides a mechanism able to dynamically manage information about the status of users, equipments and services, thus posing a great opportunity to deploy feature-rich services in the ITS context.

In this paper, we propose an architecture that integrates IMS in the ITS domain, to provide telematic services over a common framework, and decoupling the IMS architecture defined by 3GPP from cellular networks. The idea has been to develop an overlay network, communication technology agnostic, for the management, deployment and delivery of services in ITS field. Among other functionalities, the proposal has been extended with the design and implementation of a service deployment scheme based on the Presence Service. The whole work comprises both design and implementation issues, including various service prototypes in order to demonstrate the potential of the solution.

The structure of the paper is as follows. Section 2 introduces IMS and its application in the vehicular field. After that, several related works are presented in Section 3. Section 4 details the architecture of the solution, dealing with the integration of IMS entities and basic services. Section 5 explains the development of the presence-based service platform, and details how ITS telematic services can benefit from the solution. Section 6 describes the service prototypes implemented as a proof of concept. Finally, the work is concluded in Section 7 with future works and emphasizing the importance of the IMS-based platform for the provision of new services in vehicular environments.

2 IMS background

2.1 3GPP IMS core

The 3GPP IMS is an architectural framework for delivering IP services on a common platform. It consists of a standardized set of functions that cooperate and are usually matched to different nodes. These are common recognized entities in most of the the IMS implementations that perform a well-defined task. The IMS specification has been designed to enable operators to provide a wide range of real-time and packet-based services by which users can be charged. It also provides a framework for deploying both common calling capabilities and advanced telematic services [3]. The heart of the IMS network are the Call Session Control Functions (CSCF), typically a SIP server with a customizable behavior. CSCFs process SIP signaling providing registration and session establishment capabilities. It could be said that CSCFs conform the routing machinery of the IMS [4]. IMS core entities are:

- Proxy CSCF (P-CSCF). It is the entry point to the IMS domain and serves as the outbound proxy server for clients.
- Home Subscriber Server (HSS). It is the central repository for user information, including identity management and user status. It holds any required information to handle user registration and session establishment.
- Serving CSCF (S-CSCF). It is the brain of the IMS core, by processing registrations of terminals with the IMS domain and managing calls to service endpoints. The operation of the S-CSCF can be configured by modifying the policies stored in the HSS.
- Interrogating CSCF (I-CSCF). It acts as an inbound SIP proxy server. On IMS registrations, I-CSCF queries the HSS to select the appropriate S-CSCF which must serve each user. The I-CSCF routes the incoming session requests to the S-CSCF of the called party.
- Subscriber Location Functions (SLF). It is a database that maps users' URI to the associated HSS (in case more than one exists).
- SIP Application Server (SIP-AS). It is the native IMS application server, and serves as host for the execution of IP multimedia or non multimedia services based on SIP signaling.

2.2 3GPP IMS Emergency Sessions

Recently, 3GPP has extended the IMS architecture to provide Emergency Call services (e-Call). To do so, new IMS functions have been included:

- Emergency CSCF (E-CSCF). E-CSCF is usually implemented as a SIP Server, as the rest of CSCFs, and it is responsible for handling emergency session establishments and termination [5].
- Location Retrieving Function (LRF). This functional entity handles the retrieval of location information for the User Equipment (UE).

When UE registers with the IMS network with a special emergency flag, it tries to identify its own location by asking the LRF. With that information, UE sends a call initiating message to P-CSCF, which ignores the roaming restrictions of the subscriber (since it could be connecting with a visited IMS domain) and whether the user is registered or not, and then forwards the request to the nearest E-CSCF. E-CSCF determines then the address of an appropriate Public Service Access Point (PSAP) and routes the call to it, thus completing the call establishment. The PSAP is the demarcation point between the IMS network and the Public Switched Telephone Network (PSTN), and will be in charge of managing the emergency situation according to the data provided.

2.3 3GPP IMS Presence Architecture

Over the IMS core functions, 3GPP also defines the Presence Service (PS) based on the IETF presence model specifications known as "SIP for Instant Messaging and Presence Leveraging Extensions" (SIMPLE) [6]. PS accepts, stores and distributes presence information based on SIP messages. In that model, presence is understood as information published by users (presence entities, abbreviated as presentities) to other users (watchers) to indicate their ability and willingness to communicate [7]. Therefore, a presentity provides information about its own presence to the PS. This presence information is then redistributed by the PS to all the IMS entities subscribed to this presentity. A presentity can have several devices capable of sending information about the user, these are known as Presence User Agents (PUA). In fact, PUAs send presence information to a Presence Agent (PA), which is the part of the PS responsible for storing and forwarding Presence Information to all the involved watchers.

In the proposal given in this paper, developed services can also use IM for sending/receiving messages during a session, also following the SIMPLE framework. In fact, one of the most powerful advantages of our platform is the integration with advanced NGN enablers. These enablers (also known as SIP-AS) provide common functionalities to services that they can reuse, delegating critical operations to a trusted reliable entity. Some examples of enablers are: identity provisioning, authentication, authorization, location server, broadcast service, user profile, multi-conference, instant messaging and presence. These enhance consistency and reliability of new services, promoting re-use, reducing development costs and improving usability.

3GPP have defined the Presence Information Data Format (PIDF) [8] and the Rich Presence Information Data Format (RPID) [9] for exchanging presence information, although they have been extended in this proposal. PIDF defines a compact model to describe the presence information of a presentity, whereas RPID allows a presentity to send detailed and rich presence information to her watchers.

Going a step further, 3GPP has also extended the base PS with new optimizations. Usually, each time a watcher wants to subscribe to a presentity, it have to initiate a subscription transaction. This signalization follows a path from the UE of the potential watcher to the UE of the presentity, what cam implies too many hops if the terminals are in different domains. To solve this problem, the IETF created the concept of resource list. A resource list (also called presence list) is a list of SIP URIs that are stored in a new functional entity called Resource List Server (RLS). RLS receives watcher subscriptions to presence list URIs (since a presence list has its own URI) and automatically performs the subscription process to all the presentities in the list. When using an RLS, the presence list is stored in an independent reliable network entity rather than being stored locally in the presence user application. Moreover, the RLS not only carries out all individual subscriptions, but it also combines presence information from presentities in a single message delivered to watchers of resource lists.

This work integrates PS, the RLS function, and the XML Configuration Access Protocol (XCAP) to manage resource lists. XCAP is a XML-based protocol which provides capabilities to add, modify, and delete XML configuration data stored in a server, such as users in a presence list, authorization policies or a list of participants in a conference. XCAP is transported over Hypertext Transfer Protocol (HTTP). According to the Open Mobile Alliance (OMA), XCAP is the protocol used for the XML Document Management (XDM). The current work integrates an XDM Server (XDMS) to manage contacts lists and presence rules for each presentity, as it is described later.

3 Related Work

The use of IMS in ITS as a platform to deliver services has not been sufficiently exploited yet, although some solutions in this line are available in the literature. The iRide [10] proposal comprises an IMS-based service, with an associated client application, for warning drivers about hazardous situations on the road. For this purpose, a multi-hop wireless sensor network is deployed along with a wireless infrastructure for connecting IMS clients to the core system. Once in the main system, data provided by the sensor network is transmitted to an application server that hosts the IMS service. This processes the received information and alert drivers about dangerous situations, although this communication flow is not specified in the proposal. A similar work is presented in [7], where a wireless sensor network is also used to monitor health status data in order to establish an emergency call when needed. The example given here tracks heart conditions, and automatically establishes a 911 call with the PSAP upon the detection of an incoming stroke. The main problem found in this work is that a wireless sensor network is used to collect health data, and further service-level mechanisms would be needed to assure the establishment of an emergency call when needed.

The work presented in [5] focuses on IMS e-Call capabilities. It proposes to enhace the emergency functionality of IMS to provide context-aware emergency services. It proposes the management of contextual information (also captured in this work by a wireless sensor network) by the system, and the integration of this information in emergency service operations by extending the PIDF format. The retrieved information is processed and stored in a database entity, which is also responsible of managing and disseminating more contextual information provided by sensor gateways. Besides, the LRF is extended to be able to retrieve contextual information related to users. The main drawback is that the emergency service is isolated from the rest of the IMS core, and it cannot interact with other services, like the presence one.

4 Reference Architecture

The proposed architecture is based on the 3GPP IMS Release 7 [11] and the main entities are depicted in Fig. 1. Starting from the bottom part of the diagram, the clients of the services are vehicle terminals mounted on the on-board equipment.

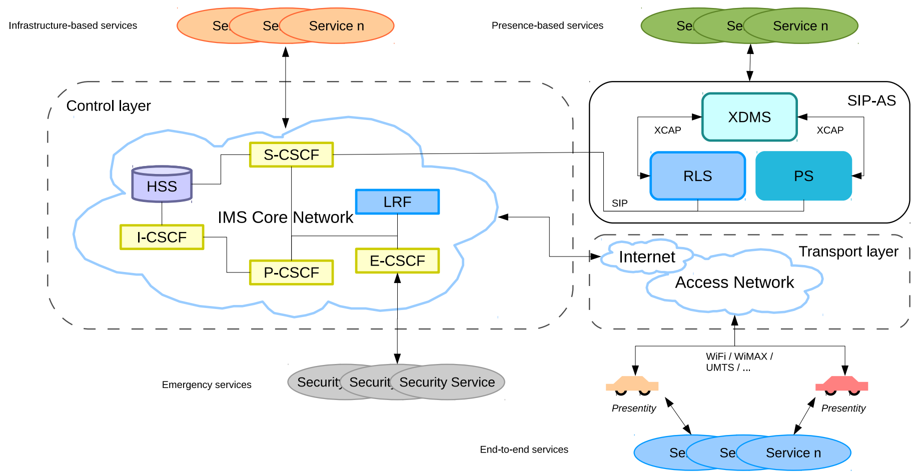

Fig. 1. Reference architecture

In the proposal, each vehicle has its own IMS identity provided in advance by the administrator of the IMS network. The IMS infrastructure is thus independent of any telecom operator. The separation of the communication technology from the potential services to be offered, leads to an access technology agnostic system. Examples of possible access technologies could be 802.11p, WiFi, UMTS, LTE or WiMAX. Additionally, the architecture provides reliable authentication and authorization to users. This feature will be essential for accessing future vehicular services.

In the proposed architecture, signalization is based on well-known and widely used protocols, such as SIP; SDP (Session Description Protocol), for capacity negotiation; RTP (Real-Time Transport Protocol) for multimedia data transmissions; or Diameter, for authentication and authorization purposes. All parties connected this overlay IMS network are identified by an unique URI.

Independently of the communication technology used, every vehicle communicates with the IMS core, composed of the three classical CSCFs (as explained before), and the E-CSCF/LRF functions, for providing emergency services. Once registered in the network, each vehicle can benefit from a series of services. The E-CSCF has an interface with both S-CSCF and P-CSCF to receive emergency registrations and emergency call session establishments, and it relies in LRF for user localization purposes. In case of a new emergency session establishment, both LRF and E-CSCF expect the GEOPRIV PIDF location object format [12] and the civic one [13]. If SIP messages do not contain this information, LRF can be configured to retrieve it form a LOCSIP server, defined by OMA Location in SIP/IP Core.

On the top of the IMS Core Network, there can be several SIP-AS hosting several IMS basic services. Those services will be described later, but one of them is the presence one. Regarding PS, the architecture presented in Fig. 1

includes some extensions. To improve the PS performance an RLS entity has been added to reduce the number of SIP messages exchanged, by acting as a proxy when a new watcher subscription is done and by merging presence notifications. Note that watchers can be far away of the IMS Core Network and connected by a limited wireless or expensive connection. To cope with this objective, RLS needs previously configured contact lists with presentities, to perform the subscription process. As can be noted, by adding this presence capabilities it is possible to easily deploy services that follow a publish-subscribe scheme, such as fleet management, vehicle monitoring and, in general, services which require the collection of data from the road side.

The architecture presented enables operators, authorities and final users to take advantage of four different types of services:

– Emergency services. These derive from the *eCall* idea, i.e. a service for accepting safety calls.
– End-to-end services. These are peer-to-peer services that extend common calls, such as videoconference, sessions for exchanging context-related information for a collaborative goal, or instant messaging between terminals. In the session establishment phase the user terminal initiates the SIP dialog and it is supervised by the IMS Core. For these kind of services, ASs do not take part of the negotiation process.
– Infrastructure-based services. These services are also supported by the 3GPP specifications, and they need both the core and a SIP-AS where to install service ends. Examples of this kind of services can follow a common client-server approach, such a contextual on-demand tourism service or a ticketing service for spectacles/museums.
– Presence-based services. These are more sophisticated services which use the presence-based architecture proposed here, such as the prototypes presented in following sections.

Presence-based services act as watchers of a resource list, this one composed of presentities (vehicle terminals) that send status information. Since vehicle terminals only maintain a connection with one PS, all information regarding all presence-based services comes in the same notification. This behavior presents both performance and privacy issues, since all watchers would receive all status data (its own ones and the ones for the rest of services). This problem is solved by using presence rules to filter in RLS the information for each presence-based service (watcher). This reduces the amount of data sent to each watcher and avoid privacy concerns, by choosing which attributes or nodes will be notified to each watcher/service. As with presence lists, presence rules can be managed only by registered users or entities, who must be authenticated and authorized to modify a certain presence rules document; hence, to make this process easier, both RLS tasks and presence rules are managed by an XDMS entity, as can be seen in Fig. 1. Presence lists are matched with concrete presence-based services with an unique SIP URI defined in RLS, which can be managed through XDMS. The service itself communicates with the XDMS to add, modify or delete presentities in its own presence list. In general, the XDMS server accomplishes the management of the XML documents and it is fully XCAP compliant, including some enhanced features. It provides authentication methods and constraint the introduction of information for each existing user within the IMS network.

5 Development of the Presence-Based Service Platform

This section explains in detail the implementation of the proposed architecture. As it has been mentioned, one of the main novelties of the proposal is the integration of new services in a presence-based platform, specially designed for the ITS field. According to our design, PS manages status publications from multiple vehicles. This includes refreshing or replacing existing presence information with newly-published information. PS is fully compatible with the IMS Core. The integration of the IMS core and this enabler has been made by inserting specific trigger points in HSS thus, enabling the S-CSCF to redirect presence SIP messages (REGISTER, SUBSCRIBE, PUBLISH and its responses) to PS.

Regarding the IMS Core Network, the Fraunhofer FOKUS *Open IMS Core* has been used. This system is largely based on the SIP Express Router (SER) project, which includes an implementation of P-CSCF, I-CSCF, S-CSCF and E-CSCF. A lightweight implementation of an HSS has been added, which works as a repository for application server settings and user profiles. A basic LRF for retrieving user location information is also given. These elements comprise the IMS Core Network and they are responsible of the session control, which is essential for supporting services.

In the first stages of the development, the Mobicents SIP Presence Service was used as SIP-AS. Mobicents is an Open Source VoIP Platform programmed in Java, which enables the convergence of voice, video and data for NGN applications. Mobicents SIP Presence Service is composed of three separate but interrelated servers, which can be deployed separately or in the same host: a SIP presence server, an XML server implementation suitable to develop our XDMS, and an RLS. These cover the necessities marked by the architecture previously presented.

Due to some instabilities in the Mobicents PS, it was later substituted by Kamailio. Kamailio, called before OpenSER, is a fork of the SER (SIP Express Router) project. Kamailio aims to deliver a similar level of flexibility and high performance as SER. It is written in C programming language and is based on several modules. The presence related modules needed are XCAP, RLS and some modules for managing XML documents. Since Kamailio can provide PS, XDMS and RLS, we can swap Mobicents for Kamailio with low effort.

Each IMS/SIP entity of our solution has been deployed on a separated Xen virtual machine with 256 MB of RAM memory, 4GB of hard disk, and two 2GHz CPUs shared among all of them. Only the SIP-AS has an increment of 1GB of RAM memory to maintain an acceptable performance when several services are installed.

For the on-board equipment, we have chosen JAIN SIP 1.2 for SIP signaling processing. This provides a standardized interface through a Java API to develop SIP-based applications and, in this case, to access the IMS infrastructure.

For the provision of status information from vehicles, the RPID model used includes extensions to support the defined presence-based services. An example of the document is shown next. The extension includes the new fields needed for a service later explained in detail. For an accurate determination of the position of the vehicle, apart from the geographical coordinates, an integrity factor about the current position is included [14]. Together with these fields, the current speed and time are also added.


```
<?xml version='1.0' encoding='UTF-8'?>
<presence xmlns='urn:ietf:params:xml:ns:pidf'
 xmlns:c='urn:ietf:params:xml:ns:pidf:cipid'
 xmlns:dm='urn:ietf:params:xml:ns:pidf:data-model'
 xmlns:rpid='urn:ietf:params:xml:ns:pidf:rpid'
 entity='sip:vehicle@open-ims.test'>
  <tuple id='t288c55b7'>
    <status>
  <basic>open</basic>
</status>
  </tuple>
  <dm:person id='pb4cedcfd'>
<rpid:activities>
  <rpid:emergency>
<dm:position>
  <dm:latitude>38.0240442</dm:latitude>
     <dm:longitude>-1.1743681</dm:longitude>
  <dm:integrity>1.0</dm:integrity>
</dm:position>
  <dm:speed>22.372652952823422</dm:speed>
  <dm:timestamp>1145534561736</dm:timestamp>
</rpid:emergency>
</rpid:activities>
  </dm:person>
</presence>
```


6 Service Prototypes

In the frame of the developed platform, some implementations have been made to validate the architecture for each of the four kind of services covered: as end-to-end service, a videoconference application has been created and installed in the on-board computer; as infrastructure-based service a traffic information channel has been implemented taking advantage of the instant messaging capabilities of IMS; as security service a reference implementation of an eCall-equivalent system has been developed to assist vehicles on emergency situations; and, finally, as a presence-based service we have developed the Access to Restricted Areas tool.

Access to Restricted Areas service allows authorities or road operators to control the access of vehicles, above all ambulances or official vehicles, to special places or road segments. When an authorized vehicle is close to a previously configured restricted area, the Traffic Control Centre (TCC) will open the access barrier. For this purpose TCC and the vehicle terminal must be registered in the service, so that any variation on the location of the vehicle will be notified to TCC when the vehicle is in "Emergency State".

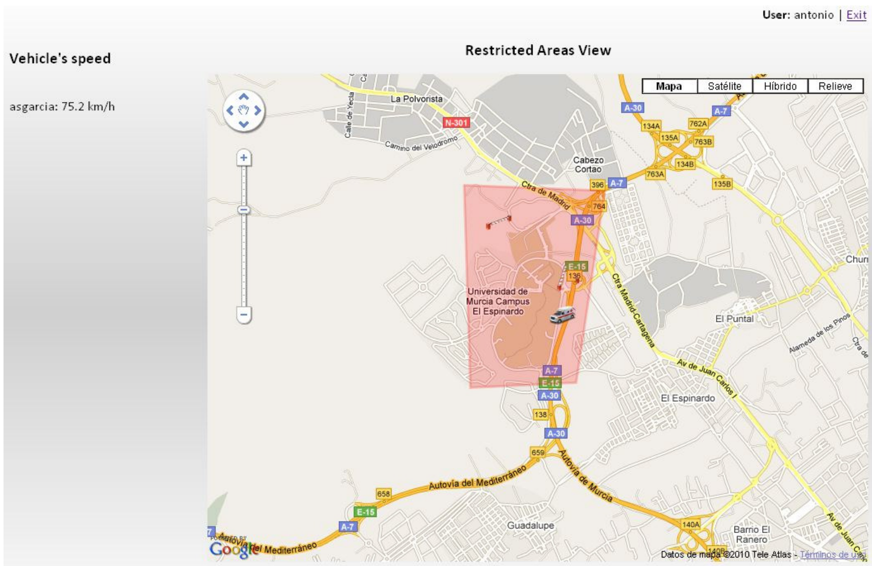

Fig. 2. Access to Restricted Areas service reference architecture.

In this service, the approaching vehicle will act as a presentity, thus using the service to dynamically publish its state ("Emergency" or "Regular") as well as its location and other contextual information relevant for TCC. The presence-base service in the platform, i.e. TCC, is configured as a watcher of every presentity in a contact list of potential emergency vehicles. The presence and location information of the presentity is encapsulated according to the model presented in the previous section, and it is periodically sent to PS, which is in charge of filtering all presence data for each service and forward notifications to them. This status information enables TCC to monitor the location of emergency vehicles, check their state, and detect wether they are approaching to a certain restricted area by matching location information with a digital map. When the logic of the service, attending these presence events, realizes a vehicle is close to a restricted area, it opens barrier automatically. The trigger distance of the vehicle towards the barrier can be configured at the TCC application, which can be seen in Fig. 2. In this screenshot an authorized operator is monitoring a vehicle in emergency state, which has just access a restricted area in the Espinardo Campus at University of Murcia. As can be seen, TCC has been implemented as a Web application that can be opened on a Web browser after an authentication stage.

7 Conclusions and Future Work

In this paper an IMS-based platform for deploying services in ITS is presented. This platform is composed of an IMS Core, basic services deployed over an AS (above all, the enriched presence service) and high-level services that take advantage of the platform. The work also analyses the many advantages found in IMS for service provisioning in vehicular scenarios. Readers must also notice that this proposal is in line with current standardization works regarding communication architectures in ITS, such as CALM (Communications Access for Land Mobiles) or the ETSI European ITS Communication Architecture, since the necessary IMS middleware on ITS stations located on vehicles, personal devices, roadside or centrals, can be placed on the facilities layer, i.e. working over transport protocols.

The deployment of advanced functionalities for vehicular services, such as service-level network authentication/authorization, accounting or the usage of base services such as presence or instant messaging, are offered with no extra efforts and efficiently by means of the proposed IMS architecture. Thus, the proposal not only enriches significantly the logic of services, but also becomes a very attractive framework for a successful growth of vehicular services by using current communication technologies. Based on the developed IMS presence service, together with the RLS functionality, resource lists, the XDMS proposal and the extension of presence notification messages, we have successfully tested real prototypes of services, such as the Access to Restricted Areas, demonstrating the feasibility of the proposal.

Regarding the performance of the platform, we must notice that ASs may collapse due to the number of notifications when presence services are used by many vehicles. However, this load can be reduced by offering more than one IMS Core domain and even including load balancing strategies with several ASs on each domain. Our work will continue by developing more services, such a novel radio-equivalent system implemented with the base Push-to-Talk functionality of IMS, and testing their performance in a wider context, involving more vehicles. Some works have also already carried out in this line, by emulating the operation of services with traffic traces generated with SUMO (Simulation of Urban Mobility). Our plans also consider integrating this IMS proposal with an IP-based mobility environment for in-vehicle networks, to test services over several network access technologies (including vertical and horizontal handovers among them) and providing network-level security by means of IPSec (Internet Protocol Security) supported by IKEv2 (Internet Key Exchange Version 2).

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