An ITS architecture specification - The FOTsis project experience

Jorge Alfonso , Nuria Sánchez , José Manuel Menéndez , Emilio Cacheiro

Abstract
The recent continuous development of Cooperative ITS has resulted in several initiatives which focus on different parts of the Cooperative environment landscape. The FOTsis project focuses on the infrastructure side of the Cooperative environment and will deploy and test 7 services designed to maximise the benefits of the integration of the road operator and infrastructure-based information providers into the ITS environment. This integration can take place in any of the stages of data collection, processing and actuations of the services, but also support and trigger external tasks such as operations of the emergency response entities, etc. This paper describes the current status of the project and focuses on the specification of the supporting architecture to the services tested: references, a brief outline of the requirements' definition, and the FOTsis architecture proposal, with some conclusions about the architecture tests conducted. The outlook on the project's next steps is given in the last section of the paper.
Keywords: Field Operational Test, Cooperative ITS, ITS Services, Architecture.

Introduction

New communication technologies open seemingly endless possibilities to the generation of new services in basically every field of the society. With the emergence in recent years of the concept first, and subsequently of the practical deployment of V2X communications, the problem with road transportation is maybe not so much one of possibilities as it is one of selecting the services' design and technologies most appropriate for the given objectives. Additional consideration is given then to the conditions which ensure a stable and consistent development and deployment framework which ensures in turn homogeneity in the implementation and provision of services, both for the users and the service providers.

It is in this sense that maybe the driving force dictating the requirements for the architectures supporting the advanced road transport services has shifted from purely the technological aspects to areas closer to Quality of Service and Quality of Experience. There is a greater knowledge know about the requirements of the users and how to specify systems that will enhance the user's experience of a service through those requirements. ITS Services are one of the approaches to this fulfilment of advancement in technological solutions with the goal of attaining user's requirements.

ITS Services

The concept of ITS service has developed as the technologies advanced, broadening the possibilities of scope and the goals of the services. However, from a technical point of view, the ITS services can be defined as aggregations of applications which make use of information and advanced technologies of sensing, processing and communications in the field of transport. Initially limited to the road transport, the concept is nowadays applied to other surface transport modes, in the shape of a "functionality provided to surface transport users designed to make surface transport safer, more sustainable, efficient and comfortable" [1].

The FOTsis project

There are several approaches to the design of ITS services, depending on who are the final users, what are the available sources of data, or what are the means to notify the final processed information to the users, for example. The current focus of the Cooperative ITS services is on the mobile entities of the road environment, therefore pushing especially concepts such as the V2V communications stack, development of on-board vehicle sensors and devices, and in general a very vehicle-oriented service design.
However there are amongst others two factors that have to be taken into account when looking at future trends in ITS Services. One is the increasing importance of the ideas of multimodality in transport, which require a different approach to data collection than exclusively road transport environments, and the other one is altogether a more practical one; there is a large amount of resources of different kinds already deployed by the road operators which might not be fully utilised in current V2V-oriented services.

The FOTsis project takes up this second factor and develops the general concept of pushing the involvement of the road infrastructure in all the stages of ITS service provision. FOTsis will specifically test the road infrastructure's capability to incorporate the latest cooperative system technology at nine test sites in four countries, as can be seen in Figure 1, providing a set of seven comprehensive service entities focusing on traffic safety and efficiency improvements.

- Service 1 Emergency management
- Service 2 Safety incident management
- Service 3 Intelligent congestion control
- Service 4 Dynamic route planning
- Service 5 Special vehicle tracking
- Service 6 Advanced enforcement
- Service 7 Infrastructure safety assessment

FOTSIS TEST SITES	
SPAIN	M-12 toll road
	A2 highway section 1
	A2 highway section 3
PORTUGAL	Baixo Alentejo
	Algarve Litoral
GERMANY	A99
	A9
	A92
GREECE	Pathe Motorway

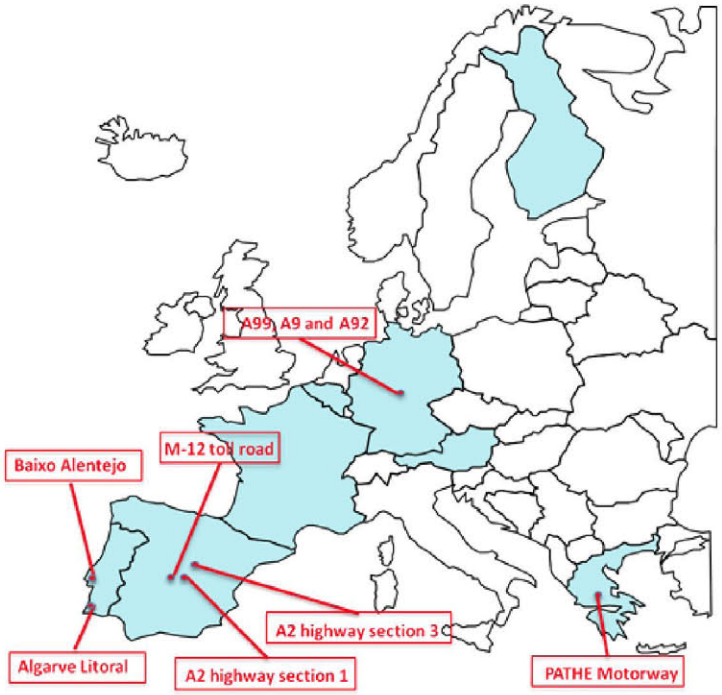

Figure 1 – FOTsis participating countries and test sites.

In the first stage of the definition of the architecture, the varied nature of the services and their different requirements and needs in terms of data collection, processing and notification to the relevant users is taken into account to provide a set of requirements for the architecture to be instantiated and implemented.

The FOTsis architecture

The overall FOTsis environment

It is important to highlight the fact that the FOTsis perspective on ITS services integrates a number of different entities, each with its role in the provision of the service. It is one objective of the project to establish the framework so that the services can take full advantage of the inclusion of these entities in the services. Briefly listed in Figure 2, besides the road user and the road operator, these additional entities include traffic management centres, emergency services and management authorities and weather data providers, amongst others.

The design of the architecture and its subsequent deployment proposal needs to take into account the relations with these different entities. The requirements for the specification of the links with different entities include not only technical aspects (physical connection between entities, network addressing and routing between domains, data exchange procedures, etc.) but also administrative aspects (authorizations, daily operation protocols and procedures requirements, etc.).

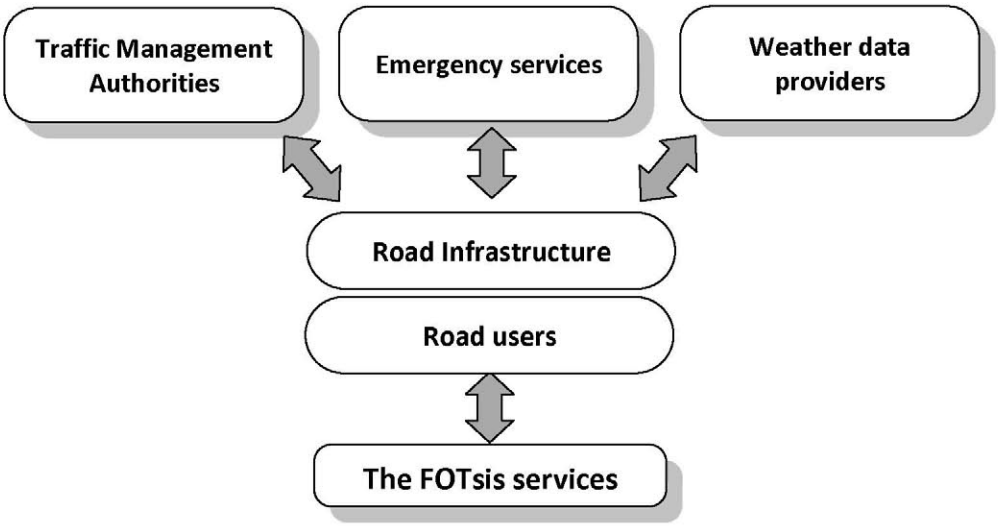

Figure 2 – Simplified FOTsis environment.

The FOTsis communications architecture

The basis of the FOTsis architecture in terms of communications is the ETSI ITS Station Reference Architecture [2]. The ITS-Station architecture, the overview of which can be seen in Figure 3.a), provides a communications framework and deployment methodology to ensure interoperability between the different Cooperative systems and services initiatives.

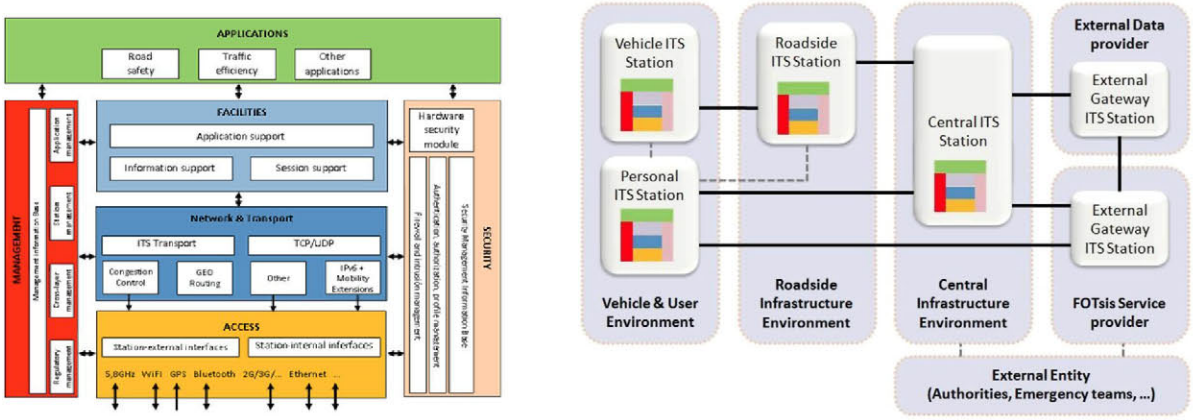

Figure 3 – a) ETSI ITS Station reference architecture general structure and, b) FOTsis Architecture basic connectivity scenarios.

Its elements have been instantiated whenever necessary, according to the requirements of the selected FOTsis services, starting with the basic deployment connectivity structure, which implies both a long distance link with the user from the Central ITS-Station at the infrastructure side of the service and a short distance link by making use of the roadside communication facilities provided by the road operator. Together with the basic links with external data providers and external service and infrastructure entities, the resulting basic connectivity scenarios can be seen in Figure 3.b).

FOTsis services requirements preliminary parameters

The definition of the FOTsis architecture starts with the specification of the requirements of the services in terms of communications basically. Special attention is paid to the link between the road users and the infrastructure, in its key role both as the first step in the vehicles' and users' data collection for the services and the FOT evaluation itself, and as the final step for the notification of service information to the users.

Parameters are divided in two types: those related to the V2X communication link (Table 1) and those more general of the services (Table 2). The first can be used to select the particular technical solutions to be deployed in the project, whereas the second can be used to setup operational specifications to those technical deployments.

Parameter	Description
Latency	Aspect related with the time elapsed between the occurrence of an incident and the reception by the user of the notification from the corresponding service. The following values are considered initially: - Real-time - Not critical - Irrelevant

Diffusion mode	Description of the relationship between the sender and the receiver of information of a service, applicable both to the acquisition and the distribution of data.
	- Directionality
	- Distribution method
	  o Unicast
	  o Multicast
	  o Geocast
	  o Broadcast

Security	In general, the aspects related with the protection of the information and processes of a service against accidental or deliberate interferences. In this case, security aspects in relation with the final user are considered: - User data privacy and protection - User communications privacy and protection

Table 1 - V2X communication link specification parameters.

Parameter	Description
Range	Aspect related to the average range of the access technology used in the link with the road user. The following values are considered initially: - Local (few meters) - Medium distance (hundreds of meters) - Long distance (Kilometers)
Bandwidth	Aspect related to the data volume intended to be transmitted through the communications link, including both peak and average rates. The following values are considered: - Low (simple signals, text) - Medium (images, audio) - High (high resolution audio or video)

Table 2 - Services communication requirements specification parameters.

Additionally, there are several requirements which need to be addressed but are out of scope of a specific service. These requirements were extracted from the general goals of the FOTsis project, namely the assessment of the capabilities of the infrastructure to provide varied advanced road services to users and vehicles.

These varied operating scenarios not only impose requirements on the more technical aspects of data collection, processing and notification, but also on the operative aspects of management of the services themselves and their associated resources, resulting in the need for the specification of a services' platform which would include several functionalities:

- Services management: advertising, start/stop, upgrade/deletion or configuration management.
- User management: ID management, sign up/registration procedures, services subscription, etc.
- Session management: communication resources management, for example.

And finally, there are requirements in relation to the links with the external entities, such as the external data providers and emergency services. From the architectural point of view, these links derive in requirements for the data exchange between entities at the application level.

The FOTsis architecture deployment proposal

In the case of the FOTsis services, the requirements in terms of the parameters listed above resulted in a choice of communication technologies which can be summarised in the following main guidelines:

- At the Access layer, use of a combination of 3G + DSRC
- At the Network layer, use of an IP-based scheme
- At the Application layer, use of web-based services and a generic application deployment platform. Some data exchanges must comply with applicable standards.

The use of a combination of short range and long range radio link with the road users serves to maximise the connectivity time for the services, while exploiting in certain cases specific advantages of either alternative. IEEE 802.11p hotspots located nearby relevant areas of the road infrastructure enable the transmission of localised data to and from FOTsis entities in a very controlled way. These hotspots enable certain service functionalities such as network-based vehicle positioning instead of GPS-based positioning, which can be used as a localised point-based data collection and dissemination tool [3]. 3G on the other hand allows for a greater coverage in areas where the deployment of short range equipment is not complete, while still complying with the services requirements.

The need to ensure the connectivity with a diversity of entities and the flexibility of the technology itself has made IP recommended for the FOTsis services deployment. IP includes long established extensions for mobility [4], and security [5], as well as the capability to operate over other Cooperative ITS network layer initiatives such as GeoNetworking protocols [6]. FOTsis thoroughly explores the IPv6 developments in the areas mentioned above, using project's expertise in the field but also through a cooperation with the FP7 ITSSv6 project, which aims to complete, implement and validate IPv6-related ITS Station standards [7]. The use of IPv4 in some of the elements of the FOTsis deployments means that besides IPv6, mechanisms like dualstack and MCoA amongst others are also being used.

Web-based services have shown flexibility and ease of deployment, which suggests that in certain conditions it can be a viable solution for selected end-user services. The final notification of information to the users, due to its nature lends itself naturally to this approach. Other links, such as infrastructure traffic data collection or data exchange with external data providers relies on different tools because of its proprietary protocol implementations. For these cases, taking into account the limited number of external entities and the general approach of the project to make a centralised-based architecture deployment, ad-hoc connections with each entity are being used, tailored to the requirements and needs of each of the entities.

Architecture pilot tests

Preliminary tests have been conducted in FOTsis for the validation of the architecture, successfully demonstrating the data exchanges at IP level from the vehicle on-board devices, both embedded as well as user's mobile devices, to the remote service provider. These tests validate the V2I and I2V communications in 802.11n/802.11p and 3G technologies, fully assessing the performance of the lower layers of the communications architecture in terms of capacity, delays and mobility, amongst others.

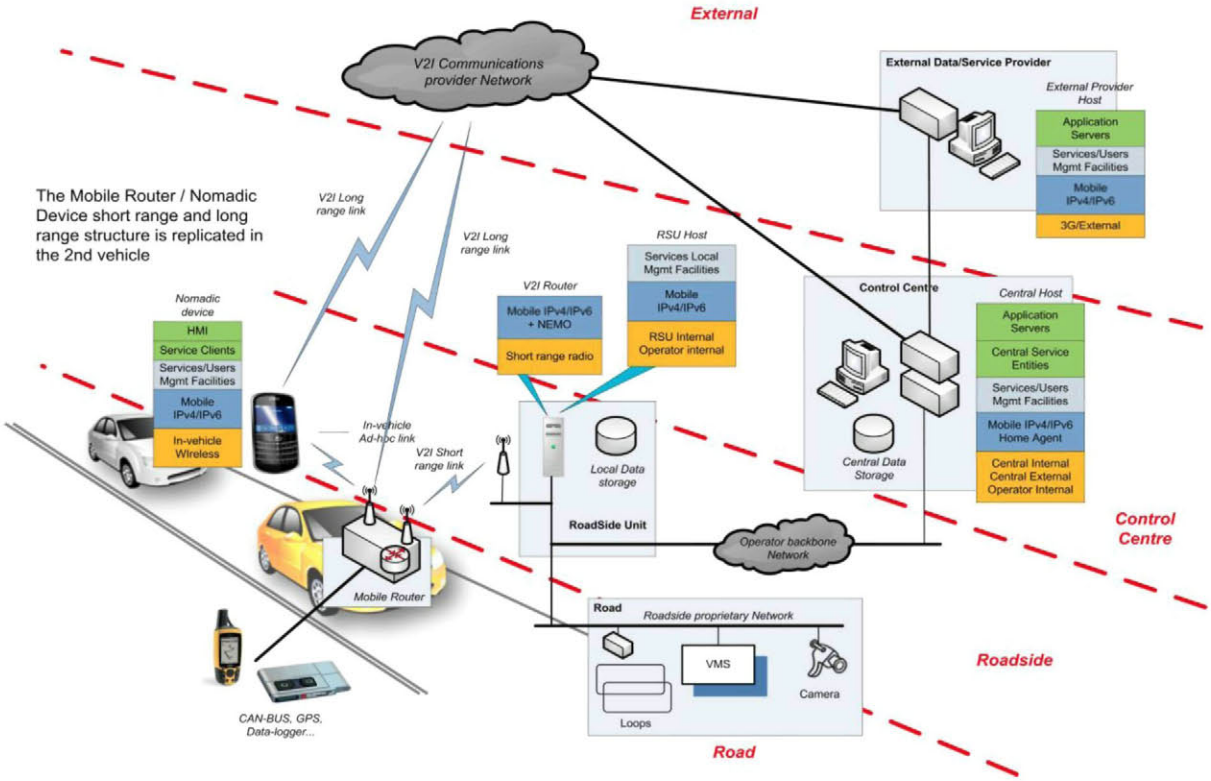

Figure 4 – FOTsis overall pilot architecture deployment.

The network architecture setup for the pilot was composed of a traffic management centre, a mobility management centre, an application server and 2 mobile routers onboard 2 vehicles. The communications were supported both by 3G and WiFi/802.11p hotspots, all messages being sent to the traffic management centre on the test site regardless of the radio technology used. The data traffic was then routed to a remote mobility management centre from where it was finally sent to the application servers at another location and back.

The final objective of the tests is to assess the performance of the complete end-to-end links of the architecture, such as the link from the road users to the service providers, or the roadside sensors to the control centre, or from the external data providers to the service providers. The tests of these links include basic connectivity tests of the different segments of the chain at the different layers of the architecture (access from on-board equipment to the infrastructure control centre, from the on-board device network entity to the network mobility manager, or to the user's smartphone service client to the application server). Detailed tests further assess the performance of these links in relation to different use circumstances which can be considered to be closer to the real use of the applications tested.

Results of the pilot tests

The tests conducted so far show a satisfactory conclusion of the deployed communications architecture. Connectivity under a diverse range of conditions meets the service requirements and the use of different manufacturer's equipment as an alternative in some cases has been resolved in a satisfactory way as well.

FOTsis services are in a way designed to make use of the available radio technologies. The provision of short range hot-spots, such as IEEE 802.11p based areas, makes it possible to improve the level of service offered to the users, and some additional specific benefits to the services. Should these short range spots not be available, services can still operate by using long range radio technologies such as 3G and offer the same basic functionalities to the users.

FOTsis architecture and services

The communications architecture is just the supporting framework for the applications which are the ultimate pieces that must achieve the goals of improvement on traffic efficiency, safety and environmental sustainability. The next steps in the project, once the architecture has been specified and implemented, is to deploy the services themselves and assess their performance in terms of the objectives above.

FOTsis is collecting data from services' preliminary tests and user tests. This data will be afterwards evaluated to see to which extent the designed services achieve the goals proposed. Data is collected regarding travel times and service levels, number of incidents and dangerous weather conditions, driving behaviour and enforcement conditions, amongst many others, to allow a thorough performance analysis of the applications.

Previous experiences have already shown that infrastructure-based services can be successfully deployed and that their contribution to the goals of efficiency under certain circumstances is positive [8]. However, FOTsis is an opportunity to validate these preliminary results and developments in a completely different environment, with a larger number of users and with an altogether more ambitious approach as described throughout this paper.

Next steps and projection beyond FOTsis

At the same time that data is collected from the vehicles, drivers and infrastructure, during the execution of the FOT, the evaluation of the performance of the services is also under way.

Evaluation procedures in a complex project such as FOTsis is in itself a complex task, including both objective data about the services, the vehicles, the users' trips and all the

circumstances surrounding the related events, as well as subjective data complementing this objective information. In the context of FOTsis evaluation procedures and the complexity of the evaluation and the data necessary, recruitment of users and the collection of user's data is also a key stage in the project. FOTsis works closely with local drivers associations to make sure that recruitment of participants meets the requirements of the project.

Procedures for analysis depend on the nature of the tested parameter and the objective under evaluation: traffic efficiency, road safety or sustainability, but always following the test conditions defined earlier in the project in terms of Research Questions and Hypotheses [9]. These are more specific questions which help to focus on a more direct answer of what are after all very broad objectives, and which in turn allow for a more systematic approach to the tests specification, data collection, impact assessment and the final analysis of the services, as can be seen in Figure 5.

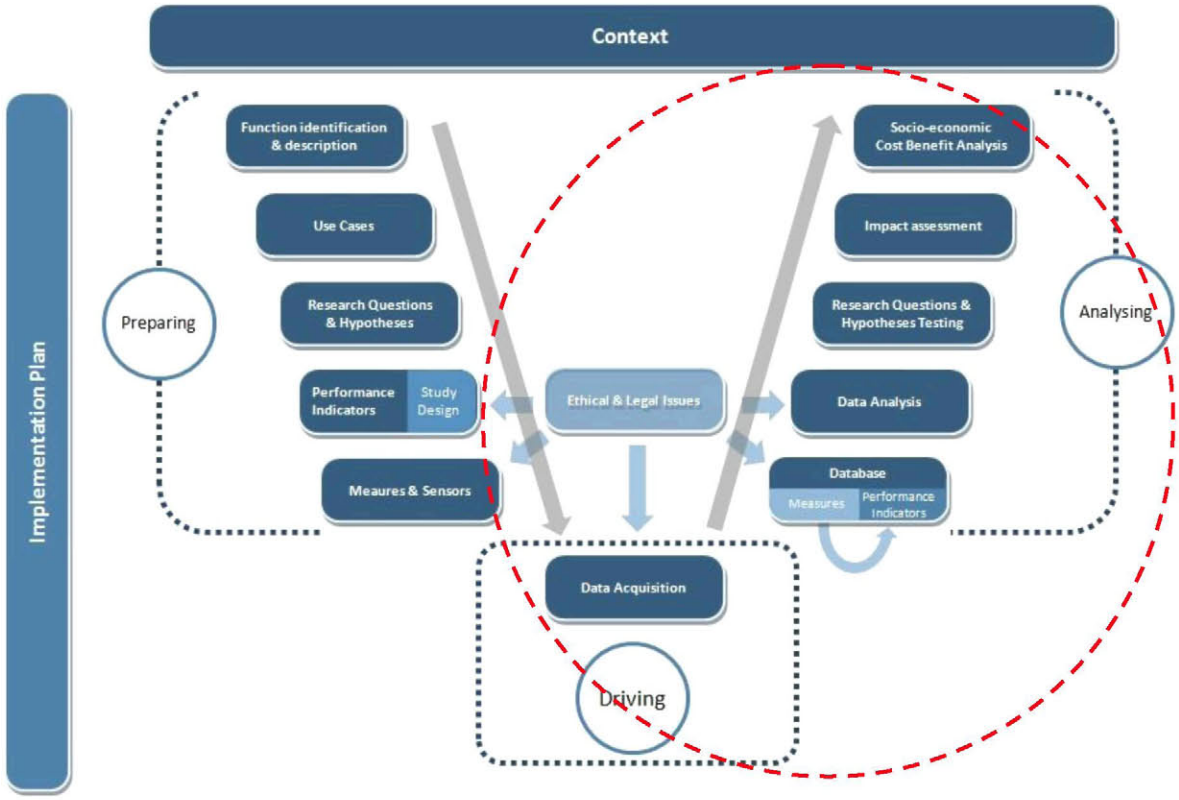

Figure 5 – FESTA FOT execution and analysis stages.

This analysis will include aspects directly related to the three main impact areas and objectives, but also aspects related to the user's experience and acceptance of the services and its impact on the user's driving behaviour. The results of the analysis in this regards could be the basis for future lines of work in which current ITS service requirements can be refined with a much more pronounced focus on the users and their experience of the service [10], with a goal additional to the traffic efficiency, safety and sustainability, in the shape of an attempt to maximise the impact that any given service might have under any given conditions for the user.

And finally, another important point to be assessed is the impact that different regional differences in terms of the regulatory framework and data exchange protocol between public and private entities might have on the deployment of complex ITS services integrating a number of heterogeneous actors. The FOTsis project offers a unique opportunity to identify the risks involved at technical level as well as at a functional and administrative level when deploying advanced complex ITS services at different regional environments, and perhaps to advance in the identification of what steps are necessary to minimise the effects of those risks.

Conclusions

The Cooperative ITS Services have the ultimate goal of using advanced communications technologies to improve surface transport in terms of traffic efficiency, safety and sustainability. In order to achieve these objectives, ITS services must integrate and process information coming from different sources to ensure that they have at any given time the most accurate image of the transport environment and the users within that environment. The FOTsis project focuses on the infrastructure side of the environment to exploit its potential as a key element of the road, as data collector, processor and actuator.

FOTsis includes 7 services designed around the infrastructure and which are expected to improve significantly the areas of traffic efficiency, safety and sustainability. The architecture supporting these services has already been designed and tested successfully, meeting the requirements identified and advancing on specific developments such as the use of 802.11p in short range links.

During the FOTsis execution, data is collected to evaluate the performance of the services and assess to which extent the objectives of the project are met. This assessment makes it necessary to gather the most information possible about all the events around the activities of any given service and the circumstances regarding all the entities involved in such activities.

But regardless of the thoroughness of the analysis, there are still areas with potential interest that even though are considered in the FOTsis project, will probably make it necessary to engage in additional future efforts to fully address the issues. Some of these areas are the need of advancing in the analysis of the impacts that ITS services have on the society as a whole and how to make sure that this impact is maximised through the individuals, and another is the identification of the risks involved in a regional deployment of the ITS services and how to minimise these risks by means of harmonising and standardising different aspects of the developments.

Acknowledgement

This work has been funded under the FOTsis project which is partly financed by the European Commision in the context of the 7th Framework Programme (FP7) for Research and Technological Development (Grant Agreement no. 270447).

References

[1] ISO/TR 17465-1: 'Intelligent transport systems – Terms, definitions and guidelines for Cooperative ITS standards documents – Part 1: Part 1: Terms, definitions and outline guidance for standards documents', 2012.
[2] ETSI EN 302 665: 'Intelligent Transport Systems (ITS); Communications Architecture', V1.1.1, 2010.
[3] Alfonso, J.: 'Driving standards', Traffic Technology International, October/November 2012, pp 52-53.

[4] RFC 3775bis, RFC 3963, RFC 5944, RFC 5177: Mobility and Network Mobility support specifications for IPv4 and IPv6, IETF Network Working Group, 2005 ~ 2011.
[5] RFC 4301: 'Security Architecture for the Internet Protocol', IETF Network Working Group, 2005.
[6] ETSI TS 102 636-6-1: 'Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 6: Internet Integration; Sub-part 1: Transmission of IPv6 Packets over GeoNetworking Protocols', V1.1.1, 2011.
[7] http://project.inria.fr/itssv6/, accessed January 2013.
[8] Mejía, A. B.; Torres, J.; Alfonso, J.; Menéndez, J. M.; Merle, L. (2012). Gestión de la movilidad en OASIS. Integración de servicios para la gestión de tráfico en una arquitectura de comunicaciones V2I I2V. *XII Congreso Español ITS, Madrid, Spain.*
[9] FOT-NET, 'FESTA Handbook' (FOT-NET, Version 4, 2011)
[10] Alfonso, J.; Torres, J.; Menéndez, J. M. (2011). Towards a user goals-based multilayered architecture. *8th European ITS Congress, Lyon, France, 2011.*