Towards a Reference Architecture for a Collaborative Intelligent Transport System Infrastructure

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Abstract. The intelligent transport systems, which aim at providing smarter transport infrastructures and sustainable mobility, are deeply grounded on the Information and Communication Technologies. Current trends in the development of integrated complex systems, such as integrated road/highway concessions management, require new strategies to match business processes to the underlying technology. New road management policies, supported on new user-payer models, and increasing concerns about traffic safety, establish requirements for a new family of emergent business services. Offering the driver the possibility to extend current tolling business service contracts to make possible the access to public transport systems, parking areas, subscription to innovative insurance service, etc., all covered by a single contract, is a promising strategy to promote sustainable and safe mobility. Nevertheless, this new wave of emergent business services requires high interoperability among a diversity of (heterogeneous) technology systems considering both vehicle and road infrastructures. This paper discusses an approach to the required ICT-based intelligent infrastructure based on a collaborative network of stakeholders as contributors to the business service offering.

Keywords: Intelligent Transport Systems; Reference Architecture; Service Oriented Architectures; Collaborative Networks.

1 Introduction

The intelligent transport systems (ITS) area has its origins in the need to introduce advanced ICT support to the transport infrastructures, empowering sustainable transport policies. A first reference in this area was the formation of a group in the USA in mid 1990s, involving public transportation authorities, universities, and representatives from the private sector to propose a strategy for what was first as named Intelligent Vehicle Highway Systems (IVHS) and later as Intelligent Transportation Systems [1]. Similar dynamics were simultaneously happening in Europe and in Japan. In Europe, the programme Prometheus, established in 1986, aimed to contribute to the reduction of road accidents and to improve traffic efficiency by adopting new information and

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communication technologies [2]. In Japan a research committee RACS (Road/ Automobile Communication System) was established in 1984, followed by a three years project (1986-1989) to develop vehicle/ground digital communication. In 1987 a new project, the AMTICS (Advanced Mobile Traffic Information and Communication System) [3] was initiated. These initial synergies between transport experts and the information and communication technologies have been evolving leading to a multidisciplinary collaboration. The ITS community used to involve mainly the participation of civil engineers as experts on the processes managed in this application domain. The progressive introduction of new technologies based on electronics, communication or information management, and computing in transportation scenarios, raised the need for collaboration with computer engineering experts. As systems become more complex, only through a multi-disciplinary collaboration it is possible to achieve truly intelligent transport systems. In line with this trend, this paper proposes a strategy to address ITS by establishing a multi-layer infrastructure able to support the participation of such multidisciplinary competencies. The proposed approach is supported on the experience at Brisa motorway management company and generalizes the developed open service oriented infrastructure (ITSIBus) supporting the extension of tolling system to payment of additional services (automatic payment in parking lots and in gas stations using motorway tolling service subscription) [4].

As a base assumption, we consider that business services in this sector tend to be offered by more than one organization, leading to: i) integrated services for users (drivers, or movers in general); and ii) an increased possibility for reutilization of technological systems being at the road level or as information systems supporting the involved companies. Most of the current approaches in ITS still have a focus on specific aspects of communication or business oriented issues. In this paper we argue about the need for a holistic vision. The paper offers thus a contribution to a discussion about how to establish a reference architecture where the involved experts can identify their core contributions and at the same time understand how they fit in the overall picture (integrated collaborative solutions).

2 Towards an Intelligent Infrastructure Architecture

Systems currently used in the transport sector are not developed under a cooperation perspective. Nevertheless, the service oriented paradigm is emerging as a key contribution from the ICT area to establish a grid of autonomous computational components. If developed for the cooperation, those components are able to “participate” as components of more advanced solutions. However, a long way is still ahead in order to overcome the limitations of current technologies and development strategies so that we can achieve a really agile cooperative space able to support business services for users (persons) as compositions of autonomous computational systems (computational services). Existing systems for tolling, telematics or traffic management are computational/sensorial systems that were developed under a “closed approach” and based on low level communication standards. As a consequence, the application business logic is tightly coupled with the physical road side systems (dedicated short range communication/road side equipment - DSRC/RSE, traffic counters, Free-flows, etc.).

For instance, in the case of the infrastructure of the Portuguese highway operator Brisa, the DSRC/RSE system needs a service adapter to harmonize the plug-ability of systems from two distinct suppliers (Q-free and Kapsch), this because such systems are not ready for the cooperation. The road side equipments implement an application layer out of any normalization process, which requires the development of adaptors in order to integrate such road systems. The question is: why not embed such service adapters into the DSRC/RSE, offering a higher level language to make possible a dynamic pluggability of road systems to the community of autonomous computational entities in this domain, which potentially come from different suppliers and are developed (implemented) in a diversity of technologies (tailored for internal requirements)?

The possibility of technology interoperation in order to support a diversity of services is discussed by [5] in the context of the GNSS (GPS based) tolling, mandatory for tracks in Germany. The authors raise the possibility of promoting co-usage of in-vehicle technology modules considering the sharing of a GPS module, which is already embedded from the manufacturing stage in a significant number of vehicles, to support both navigation and tolling services. This cooperative perspective among technology modules or systems needs to cope with responsibility and liability issues. As multiple system/component providers might contribute to different services with the associated business risks, a clear framework needs to be defined. Moreover, while there are traffic systems that have a local impact, as the case of signal traffic lights and motorway ramp meter systems, according [6] "*many intelligent transportation systems are subject to network effect and scale challenges, thus requiring extensive system coordination - often needed at the national level - to deploy and integrate ITS systems*", what requires innovative networked strategies both at technical and business levels.

Therefore, the challenges of more integrated business services call for novel architectural solutions, both at the technological and at the business levels. Regarding technology, there is a need to evolve to cooperative systems, as communities of autonomous computational entities able to participate in compositions or assemblies. On the other hand there is a need for a new approach to establish a business services modeling language filling the gap both between the information and communication technology space and the processes space.

The proposal of a collaboration ITS intelligent infrastructure is derived from the need to structure *de facto* collaborative business models, which are based on the participation of a number of stakeholders (see Fig. 1). The running examples of such collaborations mostly follow a traditional ad-hoc data exchange, using manly the file transfer paradigm, although there are some trends to evolve to service oriented architectures, as the case of the Brisa's ITSIBus [4]. When involving richer information exchange, open business and technical frameworks are lacking. This leads to the need for a layer where computational services defined in a technology independent manner are able to answer business services requirements. The list of business services, as they are being discussed in the intelligent infrastructures work group (IIWG), a European Commission funded project coordinated by ERTICO, is considered to help positioning the proposed discussion. Such list groups business services in: i) travel information services; ii) traffic management services; iii) freight and logistics services; and iv) other services. The travel information services are organized as: pre-trip travel information; ii) on-trip travel information; iii) in-car incident warning; and iv) co-modal travel information.

Considering as an example of a travel information service the "in-car incident warning", we can imagine a European citizen traveling around Europe on holidays and somewhere in a highway in another country, his "dream" is to be confident that if an accident happens the on-board-computer, the OBU or its nomadic device warns him about the imminent danger. This requires in fact that a sensor in the vehicle involved in the accident broadcasts an alarm message, or eventually, some video sensor detects the incident and presents a message in variable message panels through the traffic coordination centre for the drivers approaching the dangerous zone.

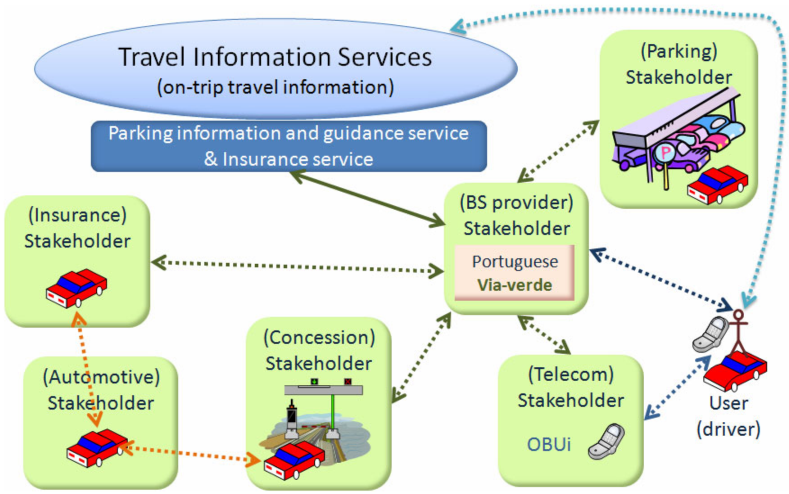

Fig. 1. Network of stakeholders offering business services based on a single contract

Considering the above scenario, there is a need to establish an agreement among the different stakeholders to establish a uniform approach on how to interact with drivers, with road coordination centers, national or European emergency mechanisms associated to the eCall initiative and why not, emergency services like rescue and medical institutions to get prepared in advance for the case they are activated by responsible authorities. If considered a pro-active coordinated system, all the interested entities (stakeholders with their own ICT infrastructures) might be involved at the same time, offering an increased and coordinated response capability. However, if the on-board system responsible for the generation of eCall emergency message does not work or gives the wrong coordinates and the vehicle is not rescued, there is a need to identify the responsibility [5].

Let us consider another example, the "parking information and guidance service", which can be classified as a "on-trip travel information" and a "travel information services" from the proposed list of IIWG, one might consider that some vehicle system or a group of cooperative systems (an OBU with DSRC+GSM/GPRS+GPS paired with nomadic device or, if the automotive industry embeds these functions in the cars as an enhanced on-board computer with its native HMI) is responsible to interact with the business service subscriber (the driver or someone on behalf of him/her). Nevertheless, the implementation of a service like this raises other challenges: the parking lots need to be prepared to collaborate with such business service. This needs for preparedness challenges not only the physical sensors infrastructure and the parking management system but also the information system of the involved parking stakeholders. Beyond free space detection and identification there is a complex business relation among the involved stakeholders that needs to be developed and coordinated.

Our hypothesis is to consider a kind of collaboration infrastructure not staying at the level of physical sensors or systems, as typical in other ITS approaches, but rather at a higher level, considering a number of logical resources able to be used to construct such proposed services involving more than one stakeholder in the majority of the cases. This configures the need to establish a collaborative network [7], [8] where the participating stakeholders need to be prepared to join business oriented associations of organizations (a kind of virtual organizations breeding environment) offering services to users and logistics in the context of mobility. The basic communication and data exchange centered approaches are not able to model the complex relationships among technical systems on both vehicle and road side systems and back-office (stakeholder's information systems). New technology patterns are necessary to cope with the technological platforms contributing to different services (the above mentioned co-usage [5]) and at the same time support collaboration and responsibility management based on a network of independent participating companies under some agreed business model.

3 Collaboration-Oriented Road Mobility Infrastructure

The proposed collaboration-oriented road mobility infrastructure (CORMI), Fig. 2, aims at establishing "bridges" among the infrastructures of different stakeholders and

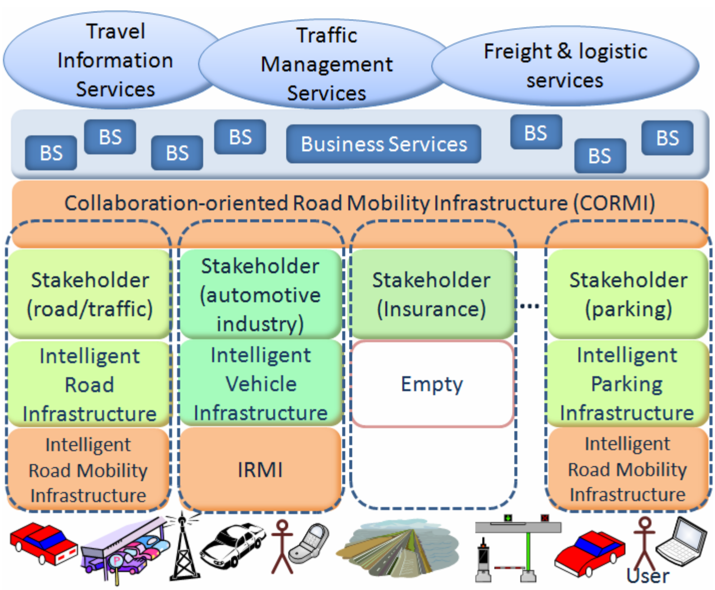

Fig. 2. A strategy to address mobility intelligent infrastructures

the moving entities (vehicles, people associated to nomadic devices). Independently, if these are vehicles or nomadic devices they should be seen as resources participating in the composition of the already mentioned business services.

In this context, it is important to see the automotive industry not as a direct contributor to the business services but rather as an organization that influences the technology and business patterns in relation how to structure such collaborative networks.

The collaboration-oriented infrastructure is responsible to provide a collaborative space where services are offered, making transparent to users the complex relations among the supporting stakeholders. While expected to share common features to other application domains, the proposal is to define specialized interfaces tailored to the transport application domain. Those shared features might be related to coordination, security, distributed information management, directory services, and authentication and authoring, common to collaborative networks in different application domains.

Therefore, the CORMI layer aims to model resources necessary to answer the business services requirements. As an example, if some analytical activity (application) associated to a business service requires to access the last two transactions in tolling and parking for a specific subscriber, these two services if defined on a technology independent approach should hide the access to specific software services implementations of the participating stakeholders who are involved in providing the required information. This approach raises a number of issues: i) where are the (computational) services running, if they are part of the information system of the business service provider or part of the information technology systems of the participating stakeholders; ii) the emerging collaborative business models generate a number of collaborative business processes with the participation of diverse stakeholders that somehow will be committed to support its coordinated and reliable execution; and iii) auditability, certification, security concerns and operational risks establishing a responsibility and market fairness framework need to be settled. To give a clearer picture about what should be the strategy for the stakeholder's organization considering a kind of preparedness state as proposed in the creation of a virtual organizations breeding environment (VBE) [7], [8] and considering that each stakeholder should maintain its autonomy, a federative approach, as in the Fig. 3, is proposed.

CORMI is responsible to promote an open services definition and shared information models for the collaboration layer [9]. The next two are internal layers specific for each stakeholder. They contribute for the collaborative efforts while following process and technology approaches not constrained by interoperability and cooperation issues. A lower layer, representing the interaction with a physical infrastructure, is implemented by stakeholders that need to support the cooperation among vehicles. This layer implements the services specified by the collaboration-oriented mobility infrastructure, thus constituting for what we propose as the effective intelligent mobility infrastructure (IRMI). Like the collaboration layer, also the IRMI layer specifies a common infrastructure (following open specifications) to all the participating stakeholders. The IRMI layer might not be implemented for the case a stakeholder does not interact with a vehicle, which is shown as an Empty box in Fig. 2. For instance, an insurance company participating on offering an insurance service to a vehicle driver based on his driving behavior, which is obtained through a specialized on-board-unit (OBU) connected to the vehicle CAN bus to access sensor data, does not need to implement the IRMI layer considering it accesses vehicle information through the other collaborative network participants (those managing road infrastructures).

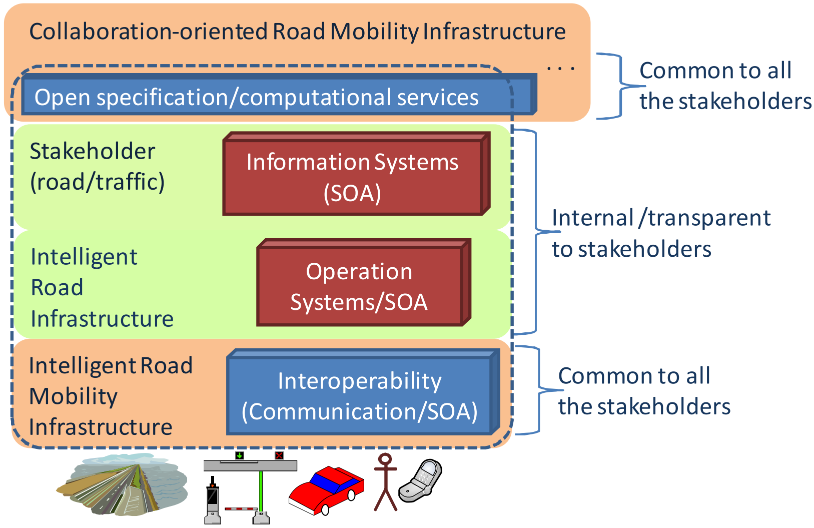

Fig. 3. The proposed architecture for a participating stakeholder

4 Related Work

Communication and interoperability issues have received most research attention in the intelligent transport systems area. Projects like CVIS, Safespot, Coopers, COMe-Safety and FRAME [10] are examples of European Research projects focused mainly on communication and basic cooperative systems while Pre-Drive C2X project extends the discussions to the backend infrastructure [11]. Particularly this project proposes an integration strategy based on a Vehicle Integration Platform and a Backend Integration Manager able to associate vehicles as moving services to services in the backend. While considering security as a key issue, the promised reference platform lacks the establishment of an open, technology independent language, able to support the cooperation between vehicle services and road side infrastructure services considering that the vehicle “crosses the space” of a diversity of stakeholders (collaborative network members).

The European Telecommunications Standards Institute (ETSI) has a technical committee for Intelligent Transport, responsible for the development of ICT technical standards and specifications for transport infrastructures, vehicles and users [12]. Nevertheless, a broader and multidisciplinary approach is needed by including other research perspectives like the distributed information systems and collaborative network organizations. As an example, the ETSI ITS reference architecture while including concepts like ITS road side station, central ITS station, operational support ITS station, and vehicle ITS station, connected through a diversity of networks (ITS Ad Hoc networks, ITS road side infrastructure network, generic access network and internet) connected to specialized routers, does not address the necessary collaboration among stakeholders to make transparent to drivers/users the technical diversity of the crossed road infrastructures [13]. Another contribution from the multi-agents area proposes a collaborative multi-agent framework for ITS focused on wireless communication between vehicles and the infrastructure without considering the situation where the vehicle is in a diversity of stakeholder´s infrastructures and how their information systems coordinate the offered services [14]. Furthermore, most of the discussions involving the communication between road side systems and central coordination information systems are based on specific data driven messaging protocols, lacking an open service oriented approach as a strategy to establish generalized collaboration among heterogeneous, multi-supplier technology systems.

5 Conclusions

A strategy based on two technology independent interoperability layers at collaborative network stakeholder level is proposed and discussed. A collaboration-oriented road mobility infrastructure layer establishes the basis for a network of stakeholders to collaborate on offering services for vehicle drivers. This layer aims to establish a technology independent specification able to be developed by each stakeholder following its processes and technology culture. An intelligent road mobility infrastructure layer is proposed for the stakeholders that have to provide connectivity to the vehicle. This road side level infrastructure is somehow an implementation of the collaboration counterpart as services accessible at physical level are also accessed on a stakeholder peer basis. This means that an insurance company holding subscribers for some insurance service will access insurance vehicle services through such intelligent road mobility infrastructure (while the vehicle might be located at different stakeholder´s infrastructure). Beyond this minimal interoperability specification, the stakeholders managing road infrastructures also maintain their specific infrastructure. A parking lot is an example of a stakeholder that beyond the specific parking infrastructure implements a number of services, those established by the IRMI.

The proposed strategy establishes a disruptive approach in comparison with the classical ITS architectures considering the proposed shift from a communication to a network collaborative centered approach. Associated to the adoption of service oriented architecture where coordination among autonomous computational services superimposes communication concerns, is the way to deal with emergent ITS business service challenges offered in a collaborative network organization.

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