SOA-based Model for the IT Integration into the Intelligent Transportation Systems

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Abstract—Currently, the Intelligent Transportation Systems (ITS) are made up of a large number of technologies that are tightly-coupled. This has led to produce many ad-hoc systems that are highly dependent and its interoperability is extremely low. The service oriented architecture (SOA) paradigm allows the construction of loose-coupled distributed systems which can help to integrate heterogeneous systems that takes part in the ITS. In this paper, we focus on developing a SOA-based model for the Information Technologies (IT) integration into the ITS. In order to develop our model, the involved ITS technologies and services were identified and catalogued. In doing so, we applied our SOA model in order to integrate and decouple all the ITS technologies and services. By developing our model, we identify that the Roadside Unit (RSU) and navigation systems are key elements to provide integration interoperability, compatibility, and expandability between ITS technologies and services. We have applied our model involving these elements in order to generate value-added ITS. A case study has been designed and implemented to illustrate the application of the model to a significant ITS service (parking management system) that includes all the components of our model.

Keywords—Intelligent Transportation System, SOA, Web Services, Navigation systems, Wireless Sensors Networks.

I. INTRODUCTION

The spread of Information and Communication Technologies (ICT) always have been a key element to develop the Intelligent Transportation Systems (ITS).

In light of this, the governments, infrastructure operators and public authorities have proposed several initiatives such as [1] and [2] in order to organize the ITS infrastructure. The proposed initiatives have led to the technology manufacturers to the creation of manifold solutions which are based on systems that are tight-coupled and that its functioning is quite ad-doc. All of this has happened because it is highly difficult to incorporate new technologies and services without making any changes that would require the systems to be redesigned.

In this sense, in the field of ITS, traditional software methodology such as CORBA, RMI and DCOM have been used to integrate the ITS solutions, but them are so dependent on the programming language and this has provoked the creation of ad-hoc systems as well. For this reason, new emergent approaches in the field of systems integration such as the SOA paradigm are produced successful solutions which can be applied into the field of ITS. The SOA paradigm is an advance methodology that allows the construction of loose-coupled distributed systems, standards-based, and protocol independent distributed computing [3]. For this reason, the SOA paradigm along with the Web Services are becoming in new way to heterogeneous systems integration [3].

There are a large number of research works that demonstrate the importance of relationships between ITS and Service oriented architectures (SOA). Researches such as [4] and [5] focus on improving the architecture of ITS infrastructures by means of the SOA paradigm. In addition, all of them have been carried out in order to help with interoperability problems, modelling of entities and messages among the ITS components.

SOA paradigm has been used in the field of ITS to integrate the traffic centers information. For instance, this approach has been used by the U.S National ITS architecture by means of the 9010 and 2306 NTCIP protocols [6]. Likewise, there is a new European initiative called DATEX II (Easyway project still under development) [7] that follow the same aim.

In our proposal, we pretend to develop a SOA based model which can be extended to many technological elements that compose the ITS infrastructure in order to integrate the ITS technological elements and their services. In this sense, we focus on some elements that play a key role to the ITS services generation. In the first place, we focus on the Roadside Unit (RSU) that is responsible for monitoring and interacting between the Road and the traffic center, or between the road and their vehicles. Currently, the RSU is having a considerable attention as present in [8] and [9], and still more with the introduction of new embedded technologies that are producing a revolution in the computing systems. For this reason, the new embedded technologies could be used to design a new concept to the RSU devices based on SOA scheme.

In the second place, we focus on navigation systems which mostly are not able to offer dynamic information despite the fact that there are a wide variety of technologies that offers information from ITS infrastructures. For instance ITS Services such as road conditions, Traffic Jams, Road Works, Rain level, Wind speed, Slippery Road, landslides, reservation and parking location and so on could be integrated, to become them on ITS value Added services that could work on a SOA scheme.

In this paper, we focus on developing a SOA based model for the IT integration into the ITS. In order to
formulate our model, each of the technologies involved in ITS scenario were identified, catalogued. In doing so, we apply our SOA-model in order to integrate and decouple the ITS Technologies and services. A case study has been designed and implemented to illustrate the application of our model to a significant ITS service (Parking management system) that is considered by applying our model as a value-added ITS service. We have employed several emerging technologies which have been decoupled and integrated such as embedded computers, wireless sensor networks (WSN), normal computers and navigation devices to show the validity of our model. The parking service is just only one of services that model is able to support.

The remaining of this paper is organised as follows. Section II proposes the Context of the model (SOA). Section II focuses on the implementation of parking management systems as a case of use of our model, describing the test scenario and the results obtained. Section IV concludes by describing the improvements this system offers over traditional systems and the potential future works.

II. CONTEXT OF THE MODEL

The ITS scenario is made up of several different cooperative systems, such as, cellular networks, vehicular ad-hoc networks (VANETS), variable messages signs (VMS), camera networks, satellite networks, data centers, user devices (Personal digital assistants, mobile phones), RSU, WSNs, vehicle detectors, and so on. Likewise, different transportation modes (air, rail, water, road) are immersed in a variety of technological solutions that provides many services.

As of this scenario, several services involved in ITS infrastructures were identified to determine the relationships of each of them with its technological elements. From [1] and [2], different areas within transportation systems were identified and all of them contribute to the composition of the ITS services.

As of this study, we have identified that there are a wide variety of ITS services but very few of them are being consumed by the ITS users due to that, there still exist a digital divide among technologies and services.

We have developed an IT integration methodology Fig.1 from the traditional ITS services delivery model. This methodology (expressed on Ericksson and Penker UML) is made up of three processes that allow us to achieve our approach. Each process has a particular objective associate it to the process. Likewise, we have followed the recommendations of the principal international organization of standardization which will control each of processes. The processes are as follows:

A. ITS Technologies and Services Identification Process

In order to construct our model, we have investigated [10], [11], and [12] where it is possible to find several technologies commonly used in the ITS. However, all of them are not associated in a direct way with the services that support them. Hence, a relationship between the technological elements and the ITS services is needed. In fact, the ITS services are highly dependent on the vehicle’s location within the ITS infrastructure. As of this study we have created the Table I that shows the affinity among a brief summary of the most important ITS services and the technological elements that support them. The technological spectrum is quite wide and there still are manifold technologies that even it still is evolving, but we have chosen the most important ones. As shown the Table I, the Cooperative Forward Collision Warning Service can be deployed using some technological components that are depicted with a little dot. Furthermore, we have included the service scope, normally, the service scope is associated with the flow of the information (services) among the principal components on the ITS infrastructures [13], this can be Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), Infrastructure to Vehicle (I2V), Infrastructure to Infrastructure (I2I). In our case, we focus principally on I2V services and (I2I).

B. Technological Cataloguing Process

The cataloguing process for the ITS scenario is carried out by taking into account the functionalities presented by the technological elements and their involved services. We take advantage of [10], [14], and [15] to catalogue the ITS enabling technologies according to several areas such as location and referencing, data acquisition, data processing, communications, information distribution and information utilization. In addition, by considering the generation of services in context of the model, the technological elements and the ITS services were separated. For this reason, we have created two layers belonging by the context of the model which are shown in the Table II. The first layer is concerned to the generation of ITS services, and the second layer is associated with communication systems. In the service layer, three different levels were constituted in order to classify all of the elements with regard to their functionalities. The levels were classified as follows:

Figure 1.IT Integration Metodology.
the Monitoring level, the Business level and the User level. To create our service model, these levels were used to establish suitable parameters that allows associating them each other.

1) Service layer

As mentioned above, the service layer is made up of three levels, where, each of them depend on its role in the ITS scenario. Now, we describe the levels:

a) Monitoring level

This level works as the digital skin for the ITS environment, from which the information associated with ITS infrastructure is gathered. For instance, systems such as camera networks, WSNs, DSRC sensors (Dedicated Short-Range Communications), VANETs (Vehicular Ad-hoc Networks) that works as a mobile sensor network, RFID Networks, etc can be found. Each of these systems has some technological devices that act as a RSU to integrate other systems (DSRC-RSU, WSN-RSU, RFID-RSU, etc). Moreover, the mentioned above technologies works with several ad-hoc systems which provide information about some kind of events (road conditions, traffic jams, rain level, wind speed, landslides, the availability of free parking places, etc), but a large part of this information is not offer on time to the ITS users.

b) Business level

The business level serves to realize all the functionalities necessary that the ITS infrastructures required. This level gathers, processes, and stores the information delivered by several different sources, where, one of them can be the monitoring level. In the ITS scenario, the traffic management centers (TMC) play a key role, due to that from there, it is possible to control, manage, and monitoring a wide variety of parameter associated with the transportation. For instance, from a TMC not only the vehicular flow produced on the highways can be controlled but also that, it is possible to keep in touch with several critical centers such as emergency centers, hospitals, police departments and so on. The business level is made up of a large number of technological elements such as database system, storage systems (NAS/SAN), application servers (Grid Systems), and legacy systems. All of these components generate a large quantity of information that it is used in order to provide several different services that can be consumed by the user level.

c) User level

There are many entities that can act as ITS users, such as hospitals, police, roadside emergency assistance centers, or even the car drivers, pedestrians, travellers and so on.

The user level is normally supported by a variety of systems and we highlighted some of them such as, systems that are managed with specific interfaces, the user final systems, and the emerging corporative systems within ITS. As regards to systems with specific interface, it is possible to include the VMS systems due to that these systems are able to provide a visual information to the ITS users. In the case of the final users systems it is possible to include a large quantity of devices that could provide a wide variety of ITS value added services such as a PDA, smartphones, laptops, navigators, netbooks. Finally, the emerging corporate system tends to take part on this level to get much closer to their customers (pedestrian, travellers, car drivers). In the future, transport will embrace techniques used in retail, such as customer relationship management (CRM) systems and the enterprise resource planning (ERP) both to support and enhance customer relationships and with organization as well as to provide better ITS value added services.

2) Communication layer

This layer includes manifold communications systems either by wired, wireless or internetworking technologies that are founded in the ITS scenario. In the ITS context, we takes into account the CALM initiative that is still under
development [10]. Continuous Air interface Long and Medium range (CALM) provides continuous communications between a vehicle and the roadside using a variety of communication media, including cellular, 5 GHz, 63 GHz and infra-red links. CALM will provide a range of applications, including vehicle safety and information, as well as entertainment for driver and passengers [12]. As of this scheme, one of technologies that has been highlighted for generating the ITS value added services is the high speed packet access HSPA (2Mbps) belonging to cellular networks because through it, many services can be offered.

In addition, it is worth noting that in this layer as soon as possible will be incorporate the new LTE (Long Term Evolution) approach [12] that will provide a new scheme to integrate the ITS Value added services due to their features such as high speed, bandwidth, sensitivity and distance coverage. To conclude the description of this layer, the services environment must included a large number of internetworking technologies (router, switch, hubs, host) which provides the connectivity thorough all our levels.

<table>
<thead>
<tr>
<th>TABLE II. LAYERS OF THE MODEL</th>
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<tr>
<td><strong>Levels</strong></td>
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<tr>
<td>Monitoring Level</td>
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<tr>
<td>Business Level</td>
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<tr>
<td>User Level</td>
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<table>
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<tr>
<th>Communication Levels</th>
<th>Technologies</th>
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<tr>
<td>Internet devices</td>
<td>Routers, Switch, NIC, Host</td>
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</table>

C. - Technological decoupling Process: SOA-Model

In order to achieve the loosely coupling among each of layers and their levels, the SOA approach is used, due to that it will help to eliminate the constraints caused by the tight-coupled ad-doc systems. Our approach implements the SOA paradigm as Web Services. To accomplish this process, the next steps have been followed. The first step is associated with the monitoring level in which, we have used a WSNs network and another embedded device that behaves as Roadside Unit or RSU for generating monitoring services (WSN-RSU). As of this, the monitoring services are embedded as Web Services into the RSU transforming it to Roadside Unit as a Service (RSUaaS). The second step is associated with the Business level, which, by means of the storage systems is able to consume the generated services by the monitoring level. In this way, the information can be used by several systems. One of them is the application servers. These servers can generate the value-added ITS services that in turn will be offered as Web Services to user level (under SOA scheme). Here, it is worth noting that in our general model (Fig. 2) the services transactions among the levels are supported by the communication layer. Therefore, a Web Services registry-discovery system must be supported by the communication layer.

![Figure 2. SOA based Model for IT integration into the ITS](image)

Now, we describe the three phases that compose our model (Fig. 3). The first one, it is associated with the service publication, by one hand, the offered monitoring services by the monitoring level (it means by the RSUaaS), and by the other hand, the offered value-added ITS services by the business level. In light of this, the service providers are located in the monitoring level and the business level. Therefore, some of the service providers would be the WSN-RSU, VANET-RSU and application servers. All of them will register their services by means of service catalogue systems (UDDI server), where the service description is achieved through WSDL sheets and SOAP messages. The second phase is carried out when the publication phase is performed. For this reason, this phase is associated with the discovery of the offered services by the service providers. Finally, the third phase consists of the service consumption. The elements such as storage systems and the final user systems work as service consumers.

![Figure 3. Sequence diagram example for an ITS service WSN-RSU](image)
associated with the decoupling mechanisms that will allow to the model works correctly. The second part is associated with the ITS service provider that depends on level or the layer will provide a specific services to ITS consumer. At the same time, it is worth noting that the service oriented model has specific services (internal services), such as information services, that will help to the model management. The Table III details in a brief way, the obtained outcomes by applying our approach to the several ITS services.

### TABLE III. THE LOOSE COUPLING AMONG THE LEVELS BY MEANS OF SOA MODEL

<table>
<thead>
<tr>
<th>Kind of ITS Services</th>
<th>Integration and decoupling Mechanism</th>
<th>ITS Service Provider</th>
<th>ITS Consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring Service WSN-RSU/VANET-RSU*</td>
<td>SOA (SOAP)</td>
<td>RSUaaS (ML)</td>
<td>Storage Systems (BL)</td>
</tr>
<tr>
<td>High-Speed Service (VANET-RSU)*</td>
<td>Vehicular Ad-hoc Network</td>
<td>VANET node (ML)</td>
<td>VANET node (ML)</td>
</tr>
<tr>
<td>Value-Added ITS Services</td>
<td>SOA (SOAP)</td>
<td>Application Servers (BL)</td>
<td>Navigation Systems (UL)</td>
</tr>
<tr>
<td>Registry and Discovery Services for monitoring services*</td>
<td>SOA (UDDI)</td>
<td>Registry Server (BL)</td>
<td>Monitoring Services (ML)</td>
</tr>
<tr>
<td>Registry Services for Value-Added ITS Services*</td>
<td>SOA (UDDI) Services Catalogue</td>
<td>Registry Server (Communication Layer)</td>
<td>Value-Added ITS Services (BL)</td>
</tr>
<tr>
<td>Service for Information systems*</td>
<td>Distributes Systems</td>
<td>Storage Systems (BL)</td>
<td>Application Servers (UL)</td>
</tr>
</tbody>
</table>

*Internal Services, ML: Monitoring Level; BL: Business Level; UL: User Level

III. CASE STUDY: PARKING MANAGEMENT SYSTEM

A parking management system based on “emerging technologies” has been designed and developed in accordance with our approach. The system allows discovering the availability of free parking places in some parking lot. The users can access to the system through their navigation system. The parking service (considered within the 12V scope) is a value-added ITS service to the ITS users. Now we describe the system according to our approach.

A. Service Layer

1) Monitoring level

In order to develop this level, a Crossbow technology solution (MicaZ) [16] in the field of WSNs, was used for monitoring the lot parking status. For instance, when a parking place is free or busy, the motes immediately notify the availability of a parking place, by sending a message to the gateway node. The gateway node has a serial port (RS232) that can be used to integrate whole WSN to the transport infrastructure. It is worth noting that the sensor nodes were programmed using the TinyOS operating system [17]. As we have mentioned earlier, the RSU is a critical element located into the transport infrastructure through it, many monitoring systems can be integrated. In this case, our monitoring system (WSN) can be integrated through a RSU element which can be used to implement the monitoring services. As a result, we have obtained a new emerging WSN-RSU but it is still necessary to integrate these technologies under SOA scheme. In this sense, we have employed the new embedded technologies in order to propose the construction of a RSU that can handle Web Services (Monitoring Services). The RSU should be as small as possible and should support the necessary protocols to integrate it with the ITS infrastructure. According to these requirements, an embedded device called MOXA W321 [18] was chosen to implement the RSU. The device has been selected for several reasons, such as its low cost, high-speed response, Ethernet-series gateway, uClinux operating system, C and C++ standard language support and embedded Web Server (Apache). Given the MOXA features, a big challenge was to embed the Web Services (monitoring Services) stack into the device due to the memory constraints. The monitoring services are implemented as Web Services for this reason, to exchange information with the business level, the simple object access protocol (SOAP) and WSDL sheets are used. To do this, we have used gsoap library, due to their features such as adaptation to embedded devices, open source solution and is platform independent. The selected service requires that there exists a database belonging to the parking system. For this reason, we have embedded into the RSU a SQLite database that is oriented to devices with memory constraints. To conclude, the WSN gateway along with the RSU and the SOA paradigm becomes a normal RSU into a RSUaaS (RoadSide Unit as a Service) that is able to offers their services to the business level and this represents a new concept to RSU.

2) Business level

Several PC servers were used to implement the Business level. Some of them support to the database servers and some others support the applications that compose the value-added ITS services. Likewise, the business level requires that the generated data by the monitoring level to be stored. For this reason, some storage servers were used. To this level we have designed and implemented a general application to manage the Parking systems. Likewise, we have used a Web Services technology not only to exchange data between the Monitoring level and the Business level but also between the Business level and the User level (Fig 4).

3) User Level

We have designed and implemented two applications to consume the ITS value added services. The first one works through the internal WiFi Network of the University of Alicante. The application takes advantage of the Web Services technology that provides the information concerning the parking place status. The application can be installed into user devices; so, the students, professors, or other personal belonging to the University can take advantage of their services. This application was test it in several devices such as HTC Diamond 2, a pocket IPAQ H6340 (Fig 4.), and some others where, it works suitable. The time response of the Web Services was fast enough allowing to the users check the availability of a parking place while they were looking for it. The second application was developed by means of the Google Maps API, and works on line from the web browser installed in the mobile devices. The information given by the application is associated with the discovery of free parking places and it is displayed on the map. To test this application were used some mobile phones (iphone, HTC Diamond 2, HTC Hero, etc).
B. Communication layer

Some communication systems were used such as Zigbee, the RS232 standard, Ethernet and WiFi, all of these technologies helped to share the generated services with the associated levels to service layer. The ITS value added services were consumed through GPRS/HSPA links (making some requests to the application with google maps). Under SOA approach, a service registry server was used (Universal Description, Discovery and Integration (UDDI)). We have employed the Apache jUDDI (juddi-re4 version), that is an implementation of UDDI server developed in Java.

C. Test Scenario

The test scenario was carried out at the University of Alicante. We have selected an I2V service in order to test our model. The selected service was the discovery of free parking places. We have deployed 20 sensor nodes to check the availability of the parking places. In order to achieve our approach, the SOA paradigm is applied on an embedded device becoming a normal RSU into a RSUaaS.

IV. CONCLUSIONS

In this paper, we presented, tested, and developed a SOA-based model for the IT integration into the intelligent transportation systems. Our approach has allowed to achieve a loosely coupling among each of the technologies and services present in the ITS scenario. We developed a new concept to the RSU device that we called RSUaaS. Our approach allows for exchanges services between the several levels mentioned belonging to our model. For this reason, the ITS value added services can be offered and deployed on the navigation system. We have also used a new emerging technology (WSN) that serves to create a WSN-RSU within a services environment. The model was tested with a ITS service and more services will be added to our future work.

REFERENCES