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VISIONS: a Service Oriented Architecture for Remote Vehicle Inspection

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***Abstract*—This paper presents a system for remote vehicle inspection developed within the VISIONS (Vehicular System Interface for Open Network Service) research project funded by the European Commission. The system architecture allows digital service exchange between vehicles and road infrastructures (e.g., road, tunnel, terminal containers) and makes available a large set of significant vehicle data (e.g., engine status, tire pressure, cargo documents) directly to the infrastructure information system applications. The VISIONS system, based on the Service Oriented Architecture, includes appropriate extensions to such an architecture to meet domain-specific requirements such as highly dynamic event handling and short service persistence in the network.**

The paper describes the architecture, the system prototype and the experimental results obtained in a pilot system located in the Mont Blanc Tunnel.

I. Introduction

THIS paper presents the results of the VISIONS research project, aimed at developing architectural and technological solutions for the interaction of vehicular systems (e.g., truck/trailer sensors and control units) with external road infrastructure systems (typically managed by road, tunnel, highway administrations or police, public bodies, etc.). The project defines a complete system architecture that provides a tight integration between software components running on board of commercial vehicles and ground based information systems for safety and efficiency purposes.

A. Motivation

The increasing demand for safety, efficiency, and quality of the road freight transport is at the core of the VISIONS project motivation. "Vehicle inspection" is one of the most important safety and security instruments to prevent accidents on roads, to control the legality of goods/person transportations, to limit environment pollution, etc. The actions of stopping vehicles to verify the validity of the driver's license, or to examine vehicle or trip documentation (e.g., safety cards of hazardous goods before entering a container terminal) or to check the physical status of vehicles before entering a road infrastructure (e.g., thermography at the tunnel portals), are typical examples of vehicle inspections.

Unfortunately all vehicle inspection procedures, in most cases performed with poor or no technological support, are characterized by strict trades-off, as such procedures can hardly fulfill all the following requirements simultaneously:

- *Pervasivity*: i.e., performing inspection of most vehicles populating the roads. On the contrary, for instance, each police patrol can stop only a small number of vehicles per day with respect to the total number of circulating vehicles.

TABLE I
VEHICLE DATA COLLECTION

Type	Example Data	Technologies
Vehicle status	*Truck data:* - Engine status - Fuel consumption - Brakes status - Tire pressure - Axles load - Speed	Truck CAN bus[1] Additional sensors
	Trailer data: - Brakes status - Tire pressure - Axles load	Trailer CAN bus[2] Additional sensor
Cargo status[3]	- Temperature - Pressure - Open/Close valves - Open/Close doors - Quantities	Cargo sensors
Vehicle and Cargo documents[4]	- Transport documents - Driving license - Dangerous good transport card	Stored on the On Board System

[1] All modern trucks are equipped with standard fieldbus network technologies that handle vehicle diagnostic data, such as the CAN bus. For more details about the available information, see [1].
[2] Trailer electronics is evolving to the use of standard fieldbus technologies with the aim of integrating all on board electronic equipment. VISIONS project invested on trailer electronic data management as the trailer is responsible for most of the vehicle weight and is at the origin of most accidents.
[3] VISIONS project invested specially on dangerous goods data collection, as the monitoring of such goods strongly impacts on safety.
[4] This type of data includes all information typically contained in law-enforced documents usually available in paper form. The electronic management of such documents makes inspection more efficient.

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- *Frequency*: i.e., checking the vehicle status every short time periods. On the contrary, for instance, conformity labels for pollution, or the check of the vehicle mechanical status are characterized by long term updates.
- *Accuracy*: i.e., checking all the possible parameters. On the contrary the inspection, for instance, at the entrance of the tunnel is in many cases limited to the temperature, due to lack of time and instruments.
- *Efficiency*: i.e., performing vehicle inspection in short time. On the contrary when accuracy is mandatory, for instance at the gates of a Terminal Container, severe time inefficiencies are injected in the transport system.
- *Cost Effectiveness*: i.e., performing efficient/ frequent/accurate controls at affordable costs. On the contrary, for instance, while fleet management systems are in principle good tools for inspection and appropriate standards have been developed [10], most vehicles, even limiting the scope to trucks and to information sharing only among transport operators, are not covered by such systems.

VISIONS system aims at matching all the requirements above, supporting a remote vehicle inspection procedure that allows inspecting each vehicle with no need of stopping it.

B. VISIONS objectives

The main VISIONS system functions are:

TABLE II
VEHICLE DATA DELIVERING

Task	Function	Adopted Technologies
Management of wireless communications	- Wireless networking in local area and wide area	WI-FI[1] GPRS[2]
	- Log on / Log off detection	*Logoff Service*[3]
	- Dynamic allocation of IP/ Hostname to hosts	DHCP [2]
	- Names resolution	DNS
Support of a domain-specific open interface between ground applications and on-board applications	- Messaging	XML [3] SOAP [4]
	- Service Interface Definition (SID)	WSDL [5]
	- Security	WSS [6]
Management of temporary available network services	- High dynamics service discovery - Location awareness	UDDI [7] *Trigger Engine*[4] *Location Registry*[5]

[1] In the proximity of a local road infrastructure, information passes through a wireless LAN connection. WI-FI network support higher data rates than the GPRS network and for this reason it is used in the proximity of VISIONS enable infrastructures, where a high amount of information has to be transferred, for example performing a large amount of cargo data.
[2] When the vehicle needs to transmit or receive data to or from a remote system, the mobile GPRS network is used. The GPRS network is characterized by a lower data rate but its coverage is potentially unlimited, see [1].
[3, 4, 5] See section II.B.

- Collecting vehicle data in an on-board information hub.
- Make data available to external information systems as interactive services.

1) Collecting vehicle data

The first function is to collect digital data that, at the moment, are typically produced and consumed only within the vehicle. The possibility of exporting such data represents a huge potential asset for transportation safety.

Table I shows a classification of the information related to a commercial vehicle in three main categories: data about vehicle status, data about the cargo and transport documents.

2) Data delivering

The second main function of the architecture is to make the information accessible from external information system (e.g., transport companies, transport infrastructure administrations such as tunnels, terminal containers, police, etc.), through open application interfaces. The main tasks about data delivering are shown in Table II.

The "adopted technology" column shows that some tasks can rely on well-know existing technologies while other tasks need specific functionalities, indicated in italic.

C. Roadmap

The paper is organized as follows. Section II shows the Service Oriented Architecture and the appropriate extensions of this architecture included in the VISIONS system. Section III illustrates the interaction scheme among the VISIONS system components. Section IV presents the system implementation. Section V presents the results of the experiments carried out at the Mont Blanc tunnel. Section VI provides our concluding remarks.

II. SERVICE ORIENTED ARCHITECTURE FOR MOBILE SERVICES

A. Service Oriented Architectures

The Service Oriented Architecture (SOA) [11] is an architectural approach for distributed applications that permits loosely coupled interactions between service user and service consumer. A service is a self-contained functional unit that accepts requests and returns responses through a well defined interface.

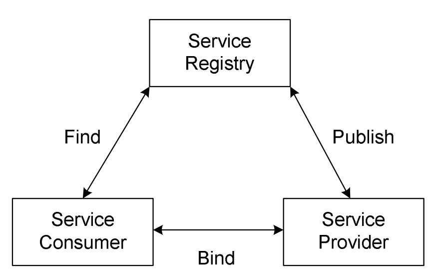

Fig. 1. Service Oriented Architecture basic interaction model. SOA defines three main actors: the Service Consumer, the Service Provider and the Service Registry. Providers publish the services they offer to a Service Registry. Consumers interrogate the Registry to discover the services they need and to obtain all the information needed to access such services.

The Service Oriented Architectures support high interoperability levels among various applications running on heterogeneous platforms and across different organizations. Thus, SOA has been selected as an effective solution for large scale integration of heterogeneous software systems, that is the exact scenario of the VISIONS project.

Web Services technologies implement the SOA approach using the standard Internet protocols. Web services are mostly implemented using SOAP for messaging [4], WSDL for service interface description [5] and UDDI [6] as service registry. In particular, UDDI stores the address of the service providers that offer a particular service and a reference to the service interface definition (SID) offered by that service. Actual WSDL service interface descriptions must be stored elsewhere, for example in a central repository, available to application developers.

Such technologies are best suited in a static fixed network environment while the requirements of the wireless mobile environment need some modifications to such rather static scheme.

B. *Mobile services*

The main architectural contribution of the VISIONS system is to extend the existing Web Services technologies to fulfill the requirements of the wireless mobile environments. The following paragraphs describe the architectural components added for this purpose.

1) *Location Registry*

The SOA Service Registry does not support the concept of service location that is necessary to keep track of the available location-related information about vehicles. The Location registry stores such information as an additional attribute of the services that reside in the Service Registry and the application can query the system filtering the request by means of location indications.

As a consequence, the Location Registry allows different users and applications to access different services depending on service location. For instance, a tunnel administration can be interested only on the truck approaching the tunnel while the police can be interested on all the vehicles within a given geographical zone.

VISIONS architecture handles two types of location information: the geographic coordinates and the point of interest. A point of interest is a place in the infrastructure, e.g. a gate, a parking site, etc. The system can associate to each service both a geographic coordinates set and a point of interest.

2) *Trigger Engine*

The Trigger Engine supports a signaling mechanism to applications when a specific change affects the Service Registry or the Location Registry. Triggers allow applications to learn when such a change happens, with no need of polling the registries. Triggers can be raised, for example, by the following events:

- A vehicle enters in the Service Registry.
- A vehicle exits from the Service Registry.
- A vehicle arrives at a particular point of interest.
- A vehicle leaves a particular point of interest.
- A newly registered vehicle provides a certain service.
- A vehicle reaches a given geographic area.

As a consequence, the Trigger Engine keeps the applications informed about the set of services available at a given moment even in an environment characterized by dynamic events such as frequent log on and log off of mobile nodes in which the service availability changes rapidly as vehicle enters and exits from the infrastructure.

3) *Logoff Service*

When a vehicle enters an infrastructure it must register its services on the Service Registry. But in general the log off is unexpected, depending on the wireless link coverage. The Logoff Service is in charge of detecting the vehicle that exits from the covering area of the infrastructure and deleting the corresponding entry from the Service Registry. For this purpose, the Logoff service must interact with the network level of the infrastructure

III. INTERACTION SCHEME

The VISIONS system consists of two main components:

1. *VISIONS Ground System (VGS).* The VGS is the part of the system that resides on the road infrastructure and that supports the interaction between the vehicles and the infrastructure.
2. *VISIONS On Board System (VOBS)*. The VOBS is the unit installed on each VISIONS enabled vehicle and it acts as an interface between the truck information system and the ground system.

Interactions between the Ground System and the On Board System are organized as a service-oriented paradigm: the service user sends a request to the service provider and the server returns the response. Both on board and ground based applications can act as provider or as consumer. So, we have

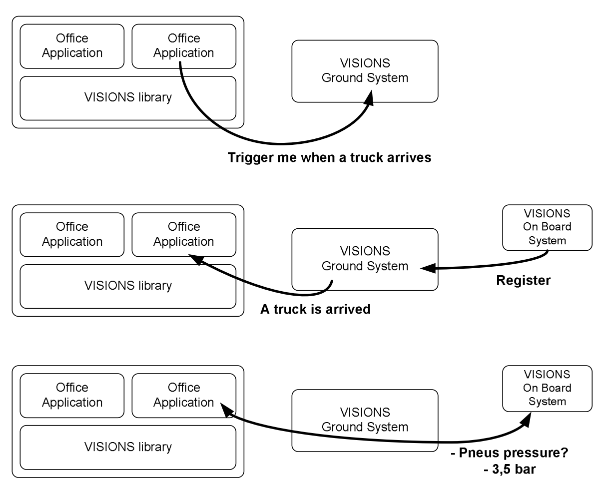

Fig. 2. VISIONS interaction scheme. Application interested in monitoring truck must register such interest on the VISIONS Ground System using VISIONS library. When a truck arrives in the covering area of a VISIONS ground system it registers itself on the Ground System and the Ground System triggers the interested applications. Finally, the application can query the On Board system for information.

two possibilities:

1. The on board application acts as a service provider. For example, a ground application sends a request for GPS position to a VOBS, and the VOBS sends a response containing GPS coordinates.
2. The ground application acts as a provider. For example, a VOBS sends a traffic information request to the VGS, and the VGS sends a response containing the report.

Fig. 2 shows the VISIONS main interaction scheme. If a ground application is interested in a particular event, for example a truck arrival in the infrastructure, it makes an appropriate subscription to the VGS. When a truck arrives in the area of the infrastructure, it registers on the system, and the VGS signals to all interested application the arrival of the truck. At the end, the application can send queries directly to the truck to get the needed data.

IV. System Implementation

The system implementation at the moment consists of a prototype that demonstrates the appropriateness of the VISIONS architecture to implement a working system.

A. Ground System

The VISIONS Ground System consists of three main functional blocks (see Fig. 3):

1. The *network block* provides a common infrastructure for exchanging information between entities in the VISIONS system, either ground or mobile systems. The communications between vehicles and the information system are guaranteed by the use of existing and mature network technologies.
2. The *identification block* allows associating a physical vehicle to the services made available on the network by that vehicle, relying on technologies such as RFID or license plate OCR. The arrival, passage or departure of truck to or from a place (e.g. a terminal) can trigger specific actions.
3. The *Registry* consists of three main components: the Service Registry, the Location Registry and the Trigger Engine. The Service Registry contains references to service interface definitions (SID) and instances to actual service suppliers. In particular, it stores a unique ID of the service provider, a reference to SID used in a particular service and the actual service address (URL). Office applications send queries to the Service Registry to discover the service they need and to obtain the address. The service registry is implemented using UDDI that, from version 2, provides a standard way to store WSDL related information [8].

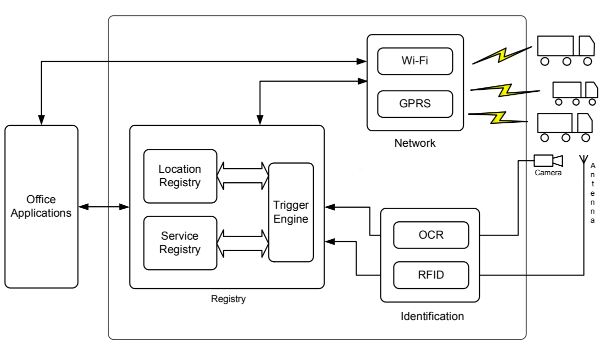

Fig. 3. The VISIONS Ground System architecture. VISIONS ground system is composed by three main blocks: the Registry, the Identification block and the Network block.

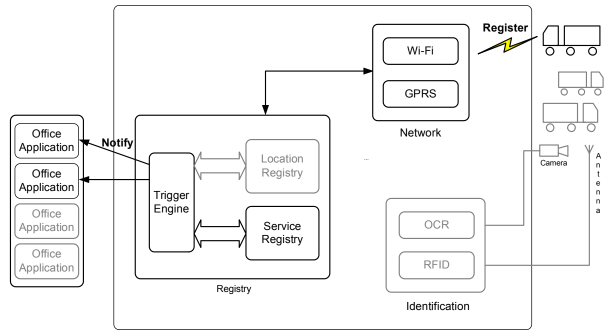

Fig. 4. Log on process. When a truck arrives in the covering range of the Ground system it registers itself on the Service registry. Then, the Trigger Engine signals the event to interested applications.

1) Location Registry

The Location Registry is implemented as a database that stores the location-related information about the vehicles. Depending on the type of that information, the update of the Location Registry takes place in a different manner:

1. *Geographic information.* The geographic coordinates collected by the GPS receiver on the VOBS are sent periodically to the Location Registry by the VOBS itself.
2. *Point of interest.* If the localization is done by the identification block the mechanism works as follows (see Fig. 5). When the identification block detects the trucks in the proximity of the point of interest, it sends the information directly to the Location Registry, without involving the vehicle.

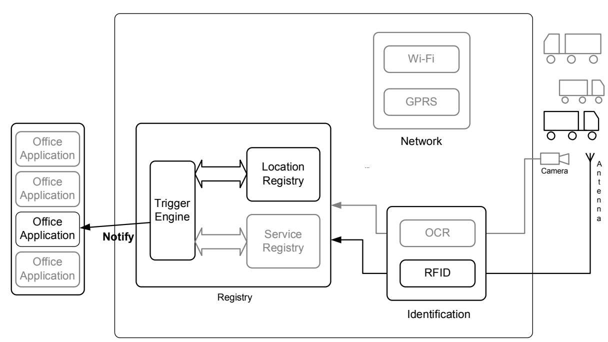

Fig. 5. Localization process. When a truck arrives at a point of interest, it is discovered by the RFID identification and the appropriate attribute is set on the Location Registry. Then the Trigger Engine signals the events to interested applications.

2) Trigger Engine

The Trigger Engine checks the Service Registry and the Location Registry for changes, and notifies such changes to the interested applications.

At this purpose, it must expose to application an interface to register their interest. The Trigger Engine acts as a Publish/Subscribe component [9] – applications subscribe to a set of events and the Trigger Engine notifies the applications when a subscribed event happens.

3) Logoff service

In the VISIONS system the assignment of IP addresses to the vehicles relies on the DHCP protocol. The DHCP subsystem assigns dynamically the (IP, hostname) pair to the VOBSs, using temporary session hostnames that are generated automatically and change at each assignment. The DHCP subsystem performs an automatic update of the DNS, which supports the name resolution of each VOBS present in the network. At the same time, it provides the Logoff Service with the ID of the VOBSs that disconnect from the system (for example, going out of WI-FI coverage or loosing GPRS connection).

When the DHCP lease time expires, meaning that the on board system has gone out of coverage, the DNS entry is removed. If a user tries to connect to a removed hostname, it will receive a 'Non-existent domain' error. The DHCP must use a very short lease time to permit a quick recognition of that event (e.g.,< 30 to 60 seconds).

The DHCP lease time and the DNS timeout parameters must be chosen carefully to minimize response time to changes without causing network overload. The Logoff service assures the consistency between the Network block and the Registry block deleting the Service Registry entries that correspond to VOBSs disconnected from the system.

B. On Board System

1) Architecture

Fig. 6 shows a scheme of the VISIONS On Board System architecture. At the bottom the system includes a block containing the Internal Devices and the External Communication devices. The Internal Devices exchange data with vehicle systems such as cargo control units or various sensors trough the CAN bus. On the contrary External Communication devices exchange data with the Ground System.

At the middle level the system includes the Data Repository and the Data Acquisition Engine. The former is a shared data base containing organized information coming from internal sources. The latter is a module interfaced with internal devices that polls data from the devices and stores them in the repository.

At the top level the system includes the Services layer. This layer represents all available services of the VOBS. Services interact directly with external systems and pick data from Data Repository, if needed.

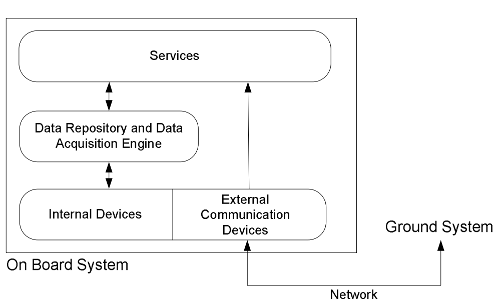

Fig. 6. VISIONS On Board System architecture.

2) The prototype

The VISIONS On Board System prototype is based on a dedicated rugged vehicular unit based on PC104 architecture. The unit can be used in harsh environments, withstanding shocks, vibrations, humidity, and achieving an extended temperature range (-25°C / + 55°C). Table III reports the main technical facts about the selected configuration.

The internal devices consist of a GPS receiver for positioning and two CAN bus interfaces to connect both to the truck CAN bus and to the trailer CAN bus. The external ones are a GPRS modem and a WI-FI interface. The unit also provides an alphanumeric display and a small keyboard to the driver.

TABLE III

VISION ON BOARD SYSTEM MAIN TECHNICAL FACTS

Dedicated rugged fanless modular system, PC104 based	
Shock, vibrations and humidity resistant chassis	
Power supply	8-30 VDC
	15 – 28 W
Weight	3 Kg
Dimensions	255 x 129 x 83 mm
Temp. range	-25 °C / +55 °C
Carrier board	Auto-diagnosis features
	Watchdog function
Processor board	Pentium class processor, 64 Mb RAM
IDE Flash	256 Mb
Interfaces	12channel GPS receiver (external antenna)
	3band GSM/GPRS modem
	802.11b/g Wireless LAN, Ethernet 10/100
	12 serial ports, 6 digital in, 5 digital out
	2 CAN bus interface
	Keyboard, alphanumeric display

V. EXPERIMENTS

The VISIONS system prototype has been tested on a commercial vehicle (truck and semi-trailer, see Fig. 7) at the Mont Blanc Tunnel infrastructure. The Mont Blanc Tunnel is a road tunnel interconnecting Italy and France, 11.6 km long and 8.6 meters wide and is one the most significant road tunnel in Europe. The Mont Blanc tunnel represents a good test site for the VISIONS system, as after a serious accident happened in 1999, the demand for high accuracy levels in the inspection of the truck entering the tunnel has become very high. At the moment the vehicle control and inspection are provided by manual inspection of the transport documents and automatic infrared screening system installed at the entrances of the tunnel, that control the temperature of the vehicle before granting the transit to the truck. The set of parameters provided by the VISIONS system is useful to grant the access only to those vehicles that match specific requirements and to monitor the parameters during the transit through the tunnel.

We have installed two WI-FI access points: one inside the tunnel and one in the French side document control area, about 10 km before the tunnel entrance. The objectives of the experiments have been to measure the performance obtained by a single access point, both on open air and inside the tunnel, including all the steps of the interaction scheme summarized in Section III. More precisely, we have considered the applicative coverage, i.e. the time interval in which is possible to perform SOAP interactions between the vehicle and the ground system.

The power settings of the WI-FI equipments have been set to 70 mW EIRP (Equivalent isotropic radiated power), below the European legal limit of 100 mW EIRP.

1) Document control area

The test in the document control area have consisted of doing six transits of the test vehicle in the WI-FI covered area, at different speeds (60, 80, and 100 km/h) and WI-FI data rate settings (11, 24, and 54 Mbps). At each transit the truck has performed the log on process, and a sample ground application requested 30 values every 300 ms, including truck CAN bus data and GPS position.

The static coverage was approximately 700 metres at 11 Mbps, 600 metres at 24 Mbps and 500 metres at 54 Mbps.

The results show that the 11 Mbps data rate (802.11b standard) permits a reliable coverage of several hundreds metres, while the 802.11g data rates (24 Mbps and 54 Mbps) do not seem to be suitable for a high speed moving vehicle scenario: in fact, at 24 Mbps the maximum speed at which we obtained a WI-FI association is 60 km/h, and at 54 Mbps such a speed is about 40 km/h.

The results obtained during the test at 11 and 24 Mbps are showed in Table IV. The first column is the vehicle speed during the run; the second column is the measured time interval of applicative coverage, while the third column is the calculated coverage (in metres, obtained from the first two columns). The fourth column (Ntime) is the calculated time interval between the vehicle entrance in the WI-FI coverage and the start of the first successful SOAP interaction. This delay to the applicative data exchange consists of three phases:

1. The WI-FI association phase
2. The IP assignment phase (DHCP)
3. The service registration phase (UDDI)

Our tests show that phases 2 and 3 take about 4 seconds, while the first is longer. In the static case, NTime is about 10 seconds, increasing in the dynamic scenario to 15-20 seconds, due to the effects of the speed.

Fig. 7. VISIONS test vehicle. The commercial vehicle used for VISIONS experiments consists of a new generation tractor attached to an electronically equipped semi-trailer.

TABLE IV
EXPERIMENTS AT THE MONT BLANC TUNNEL DOCUMENT CONTROL AREA

11 Mbps			
Speed (km/h)	*Coverage time (s)*	*Coverage (m)*	*Ntime (s)*
60	25,3	422	16,7
80	16,6	369	14,9
100	9,4	261	15,8
24 Mbps			
Speed (km/h)	*Coverage time (s)*	*Coverage (m)*	*Ntime (s)*
60	14,7	245	21,3
80	7,1	158	19,9
100	0	0	--

2) Inside the tunnel

The test inside the tunnel has been rather limited due to time and organizational constraints, and has consisted of two transits at 60 km/h, showing an applicative coverage of about one kilometre at 11 Mbps with only one access point. More comprehensive tests will take place in September 2006, to measure the performances at different vehicle speeds and WI-FI data rates, and to analyze the coverage offered by two consecutive access points.

VI. CONCLUSION

In this paper we have presented a standard approach to automatic vehicle inspection based on a Service Oriented Architecture, making available an open interface to vehicle on board data. The paper has focused on the service reachability issues while does not discuss the security aspects issues that are another core component of the VISIONS system.

Future work will focus on the possibility to adopt a Public/Subscribe model instead of the Request/Response model, eliminating the need of polling for data that have to be monitored constantly. For example, a ground application can subscribe to the pattern “Trucks with tire pressure insufficient” and receive a notification directly from the vehicle when such event happens.

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