An Adaptive Service Platform for Traffic Management and Surveillance

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Abstract. The increasing number of road vehicles has given rise to increasingly adverse consequences in the society. Some of the major concerns that arise due to such an increase in road vehicles are: safety of the people using the road, cost and efficiency of the traffic management and the environmental footprint in terms of, e.g., air quality, acidification, climate change and noise pollution. Moreover, the increased road traffic, if not managed properly leads to severe congestion resulting into increased delay for people and goods. We argue that we can alleviate these problems when using an ICT-based service platform that supports localized monitoring and management of traffic and environmental information collected from various information sources such as sensors, surveillance camera, weather station, etc. Such information should be made available through services in order to increase reusability, loose coupling and management of different information and their analysis. In this paper, we discuss different functionalities that can be or even should be supported by the service platform and provide an architecture, following the service-oriented architecture principles, of such a platform.

1 Introduction

The mobility of people as well as goods is one of the main reasons for having road infrastructures. Motorized road vehicles have increased the efficiency of mobility enabling people and goods to travel to longer distances in shorter time. The number of road vehicles is increasing with the increase of populations as well as their socio-economic interests. This has caused the saturation of road infrastructures and has ultimately affected our daily lives. This increase in the number of vehicles has in fact given rise to increasingly adverse consequences not only in the lives of individuals but in society as a whole. Some of the major emerging concerns are: safety of the people using the road, cost and efficiency of the traffic management and the environmental footprint in terms of, e.g., air quality, acidification, climate change and noise pollution [1, 2]. The increased road traffic, if not managed properly leads to severe congestion resulting into increasing delay for people and goods.

Several attempts have been made for developing smart infrastructures and systems to efficiently manage the road traffic [3–7]. Collection and processing of road users data is performed using information and communication technologies. These systems

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and infrastructures are developed independently and are embedded in different vendor-specific systems. This makes it difficult for most of the current road users to take full advantage of these technologies due to the lack of a suitable service platform with shared conventions and standards. The existing solutions heavily rely on centralized servers and do not consider the information available at the surroundings of the the users (e.g., information available at the nearby user) [8]. Moreover, these solutions are designed to assist managing the road infrastructure and therefore the drivers are unable to utlise the instantly available information in their surroundings. For example, it is more appropriate to ask the vehicles ahead for the road condition instead of asking such context-dependent information from a central system.

To resolve the above mentioned issues, we need a context-aware service platform where interacting services coexist. Such a platform should provide support for: 1) uniform access to data and functionality offered by individual system providers and 2) seamless communication with vehicles as well as other services systems. In order to support this, the service platform should deal with localized monitoring and management of traffic and environmental information collected from various information sources (e.g., sensors, surveillance camera, weather condition, etc.). These information sources can be made available as information providing services. The services approach is required to increase reusability, loose coupling and management of different information and their analysis, which is otherwise inefficient because the services platform has to deal with an enormous amount of data. The services approach also allows for the provisioning of the services on the cloud which is useful in achieving performance requirements such as scalability and efficiency.

Since the service platform has to deal with real-time information several challenges exist. We need to define a service description that allows to specify context information. A service composition framework capable of utilising real-time (context) information is required to provide useful information to the road users. This composition framework should be guided by service intelligence to exploit knowledge acquired from analyzing observed behavior of the road users. It is also required to deal with service management (e.g. lifecycle, versioning) because the services need to be composed on a per user basis and are usually short-lived. Generic functions available in vehicles (e.g., cars) like speed information, engine parameters, gas usage etc. need to be provided using standardized interfaces. The differences between existing vendor-specific technology platforms and applications have to be bridged by an open service platform for the automotive industry. Automotive telematics services have to be identified, satisfying the needs of the business domain and using the technical capabilities of the network and sensor domain. Such services, possibly run on the open service platform, may also interact with information and computation services in the public domain, e.g., in the cloud, in order to reach its full potential.

In this paper, we focus on the problem of providing a services platform to support communication and coordination between road users, road infrastructure services and third party services. Through such communication and coordination, it is possible to increase road safety, to decrease environmental pollution and to increase the level of comfort of the drivers at the road. To define this service platform we follow the principles of service oriented architecture [9] and context-aware computing [10, 11]. The service oriented architecture (SOA) allows for the integration of varieties of services and technologies whereas context-aware computing allows for real-time adaptation system behaviour according to the changes in the users environment.

The rest of the paper is structured as follows: Section 2 describes an application scenario to motivate the requirements of the work presented in this paper. Section 3 highlights technical challenges that need to be considered while providing a service platform in the traffic domain. Section 4 presents an initial architecture of the proposed service platform based on SOA principles. Section 5 discusses some related works. Section 6 points some of the issues that needs to be further considered and Section 7 concludes this paper with some suggestions for future work.

2 Application Scenario

Bob lives in the outskirt of Enschede with his wife and two children. He is scheduled to have a project meeting in Sofia at 11:00 PM on Friday. He is occupied the entire day because of the kick-off meeting of his recently acquired project on Thursday. Because Bob is mostly busy with his work (delivering lectures, attending meetings, and doing research) during the weekdays, he spends his weekend with his family as much as possible. When his children know about his forthcoming trip to Sofia on Friday, they were sad that they will not see him during the weekend. So he promises his children that he will return to take them to the world-famous zoological garden in Emmen at the weekend.

He decides to travel Friday morning to Schiphol where he will take an early flight to Sofia. Since taking a train would not leave him enough time to check in, he takes his car, which is equipped with Intelligent Route Planning (IRP) agent, radio and Global Positioning System (GPS) devices.

He books the flight accordingly and downloads his e-ticket to his smartphone. When the e-ticket is downloaded, his smart phone recognizes it and wirelessly communicates with an IRP agent installed on his car. This agent communicates with the GPS device installed on the car and determines the required travel time to reach to the Schiphol airport. The IRP agent, knows that Bob normally wants to arrive at the airport 30 minutes before the normal time as suggested by the airlines and thus calculates the time Bob needs to start his journey. The IRP agent communicates this information to Bob's smart phone. Bob's mart phone then uses this information and sets his alarm accordingly.

When he follows the route shown on his GPS system, he suddenly encounters that the road is blocked because construction works. He then ignores the advice from the GPS system and drives on a different road than suggested by the GPS system. The GPS system apparently does not know about this situation and road that Bob is driving because it is a newly constructed road, it keeps advising Bob to take a U-turn if possible. Bob keeps ignoring the advice and keeps driving using his own instinct and sense of direction. After a while, the GPS system recognizes the stretch of road that Bob is driving and recalculates the route for Bob. The road that Bob was driving based on his own sense of direction turns out to be a faster section of the road in early morning travel time. The IRP agent on his car records this newly discovered route and updates the map and broadcasts the plan to the passerby cars.

While on his way, the IRP agent installed on a car coming from the opposite direction communicates information of long jam of cars 10 KM ahead because of a recent accident to the IRP agent installed on Bob's car. The IRP agent then communicates this information to the GPS system to re-calculate the route.

When he is driving on the re-calculated route, the IRP agent communicates with the Road-Side Infrastructure (RSI) and finds out that the traffic near the next junction where Bob has to turn right is congested (the RSI can determine such a situation by using information from loop detectors). The IRP agent informs Bob to change the lane well in advance. The IRP agent also predicts, based on the current weather conditions, total number of current road users and their average speed, that the joining road ahead of the next junction could have black ice. The IRP agent then informs Bob to drive at safe speed to avoid a possible slippery road condition.

When Bob drives some 100 KM, The IRP agent receives information from the RSI that there is a poor visibility 20 KM ahead of the road and schedules the light control system to brighten their light calculating the time required to reach that spot. When Bob passes the poor visibility area, the IRP agent identifies that the visibility is OK and resets the high to their original intensity through the light control system.

When at parking lot at the airport, Bob's car recognises that his friend Dave is also at the airport, and sends him an invitation for a coffee if he has time. Dave replies with a call and they meet at a nearby coffee shop. After having a chat with his friend, Bob goes to check-in his flight and leaves for Sofia.

After his meeting in Sofia, Bob returns to the Netherlands. When he lands at the Schiphol airport, he turns his smart phone on. His smart phone then wirelessly communicates with the IRP Agent at his car. The agent then communicates with the GPS system and calculates the time required to reach his home and informs his wife Alice about his arrival time. Bob then continues his journey towards his home following the route displayed on his GPS system.

After driving 45KM, the road RSI communicates to the radio device installed on his car that the road further ahead is busy (which is expected because it is a Friday night). The RPI agent receives this information through the radio device installed on Bob's car and communicates with the GPS system to recalculate the new route and new time required to reach Bob's home. It appears that Bob will arrive home 30 minutes later than previously expected, the IRP agent then informs Alice that Bob will be late by 30 minutes because of busy traffic.

The new road that Bob is driving now is relatively empty ahead of him, however there are few cars behind him. When he approaches Enschede, the IRP agent communicates with the RSI and finds that an ambulance is coming on the joining road at the junction ahead and Bob will not be able to cross it safely. The IRP agent then informs Bob to slow down because the traffic light at the junction is going to turn red because of the high priority vehicle on the other road. When he starts decelerating, the IRP agent communicates with the IRP agent on the car behind Bob (which was out of the range of RSI communication) and informs that Bob is decelerating. The IRP agent on the car behind Bob then informs his driver Tim to start decelerating to avoid possible environmental pollution (noise, air) and a possible collision because the car in front is decelerating for some reason.

When the ambulance crosses the junction, RSI broadcasts the message that it is going to turn the traffic light to green because there are no other vehicles on the joining road. The IRP agent informs Bob to smoothly accelerate and move forward. Finally, when Bob arrives at home, Alice is waiting for him with a hot cup of coffee, he starts talking with Alice while drinking his coffee.

2.1 Functional Requirements

Based on the application scenario described in Section 2, we define a set of functional requirements that should be provided by a service platform. Below we describe some of these functionalities and the information required to provide these functionalities.

Lance Changing. The lane changing is one of the complex tasks, which needs to be decided by the driver based on the current situation at road. There might be various reasons for decising on changing the lane while driving on the road. Drivers need to assess the situation, find the appropriate gap, ensure there is no bliend-spot situation and make the decision instantly. The reasons for changing the lane could either be mandatory or discretionary. It is mandatory to change the lane when the current lane is ending or the vehicle is facing the hazardious situation or the driver intends to take a turn at upcoming junction and therefore the vehicles needs to be on the different lane. It is discretionary to change the lane if the preceding vehicle is driving slower than normal speed. In such situations drivers can be assisted to change their lane safely based on route calculation (e.g., turn left at next junction) or current traffic situation (e.g., overtake to move faster). While assisting the drivers, bliend-spot situation must be assesed based on run-time information possibly collected through inbuilt sensors to prevent possible crash with a nearby vehicle.

Curve Speed. Driving at the curved can be difficult especially when the weather condition and visibility are poor. Informing the driver as far ahead as possible about the existence of a curve and the weather condition will allows drivers in negotiating curves at appropriate speeds. This will help in reducing the possible risk of sliding and unexpected crashes. This can be supported possibly by combining weather information, current speed of the vehicle, its GPS position and the digital map of the street.

Collision Avoidance. A vehicle on the road is vulnerable to collision not only because of the carelessness of its driver but also because of the actions of the drivers on other vehicles. It can also happen because of the occurrence of the unexpected and emergency events at the road. For example, icy road surface can cause the collision between cars. If emergency situation arise, a preceding car (not only the one at immidiate front but could also be the one at ten cars ahead) could suddenly break, leaving insufficient time to react safely. In such situation, drivers can be assisted based on the speed of the preceding cars which can possibly be collected by backward propagation of preceeding cars. Drivers can be informed to slow down if the preceding cars suddenly decelerate because of some unexpected reasons.

Pollution Control. Increasing number of vehicles on the road is one of the contributors to air pollution in urban areas. In fact, the driving/speeding pattern of a vehicle can be used to determine how much it contributes to the environmental pollution. The drivers can be assisted to maintain their speed at optimal level on the road thereby assisting in minimising their pollution contribution. Since the speed of a vehicle is dependent on the speed of other vehicles, weather condition, condition of the road and other situations at the road (e.g., maintenance, accident) such information could possibly be backward propagated for avoiding abrupt deceleration/acceleration of succeding vehicles.

Hazard Situation Avoidance. Drivers on the road often encounter hazardious situations. This could be because of bad weather condition, poort visibility, construction works at the road or sudden emergency etc. In such situation, drivers should be adviced in good time such that such situation can be avoided. Drivers can be advised, for example, to prepare to slow down because the road ahead is slippery or road ahead has poor visibility. In order to provide such advices, information could be gathered from different sources such as weather station, road infrastructure services or oncoming vehicles, etc.

Rerouting. When the road ahead is blocked because of some unexpected situation, it might be beneficial to advice drivers to take different route to their destination. The alternative route can be calculated based on information collected from vehicles coming from opposite direction, road infrastructure services or information from central server (providing traffic information of the local areas). Vehicles coming from the opposite direction can provide information based on their observation of the road, e.g., re-route because the road ahead is blocked due to recent accident, which may not be available through other sources.

The list of functionalities discussed above is not exclusive and these functionalities are also not orthogonal to each other. However, the list gives the impression about what type of functionalities are useful to maintain safety of the drivers, environmental sustainability as well as the management of the road traffic.

3 Challenges

In order to fulfill the requirements of traffic management and surveillance, the service platform should support integration of and interoperation between different services. The services are heterogenous in nature, i.e., they could be context dependent, short lived, localized and situation aware. Similarly, the interaction between these services could also be ad hoc and use heterogeneous communication protocols. In addition, these services has to deal with near real-time information. There are several technical challenges that need to be tackled to achieve integration and interoperation between these services in this domain.

Since the services are typically context dependent, exhibit dynamic behaviour and heterogeneous, the existing tools and technologies cannot be used as it is. We need a suitable service description model, which allows to describe not only the functional charecteristics of the services but also the context and situation at which these services can be used. This further requires a suitable composition model, which allows to compose such services based on (near) real-time information. The real-time information can be complemented with the knowledge extracted from the past behaviour of the road users. In order to support this, a suitable service intelligence model is required such that the extracted knowledge can be utilised in delivering the useful services to the users.

Drivers on the road are busy controlling the vehicle with their hands and legs occupied. This requires for a suitable iterface to the systesm such that the drivers can still concentrate on driving while being assisted. Similarly, the provisioning of services taking into account the interests of the users and the technical capabilities of the communication infrastructures and the sensors is another challenge which needs a serious attention. Moreover, providing consistency and the performance guarantee of such system is far from trivial.

4 Solutions

We describe a service platform to support communication between vehicles as well as between vehichles and road infrastructure through the concept of services orientation. The concept of service orientation is used to integrate various types of systems and services. It is also used for supporting interoperation between these services and systems. Figure 1, shows the high level interaction between these systems and services. Furthermore, the service orientation allows us to deploy services in the cloud to achieve performance requirements such as scalability and efficiency.

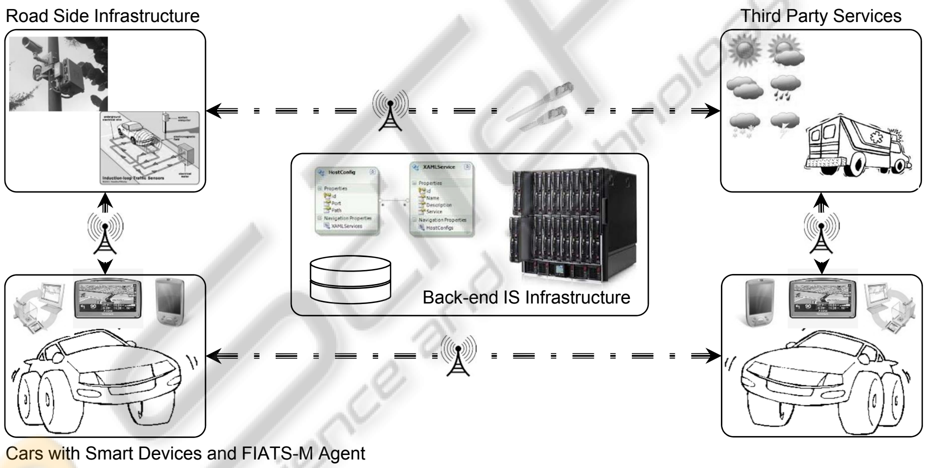

Fig. 1. Communication between Cars, Infrastructure and Services.

As seen in the figure, the service platform needs to provide supprot for different communication protocols as well as service descriptions. To supprot this requirement, the service platform provides a standard communication interface which bridges the protocol heterigeneity through the use of adapter. The heterogeneity between service descriptions can be handled by defining an intermediate description language which can allows us to define mappings without knowing the targed description language. The back-end IS infrastructure is used to process the collected information and to derive useful information or the composition of services for the user. The services can either be registered to the back-end IS infrastructure or be discovered on demand. The vehicles in the range, can communicate with themselves without requiring to go through the back-end IS infrastructure.

5 Related Works

There is significant ongoing work in the area of road traffic management and surveillance through smart technologies. An agent based approach is used in [12], aiming at providing a semantic middleware for context-aware smart road dnvironments. The context information is extracted using data mining techniquest over the collection of data obtained from various sensors.

A Peer-to-Peer based infrastructure supporting communication between vehicles and with the road-side infrastructure is defined in [10]. This work is focused on sharing context-aware road and safety information between different road users. Though their work supports such a communication, it does not spacify how up-to-date are the shared information.

In [13], an approach for supporting vehicle to vehicle communication is proposed. It employes message broadcasting as a means to support communication between vehicles. Using some intelligent communication pattern, a vehicle can notify about certain events to the nearby vehicles.

Using the color and edge information, a technique to detect traffic light is proposed in [14]. The proposed technique is defined based on image processing and statistical techniques. Detection of traffic light helps in replanning the route or suggesting drivers to stop safely at right time.

The existing systems focus on traffic management and surveillance taking into account the interests of the infrastructure providers and not the interests of the road users. Moreover, these systems do not fully utilise the collective intelligence and spatio-temporal correlations of the vehicles and their movement pattern.

6 Discussion

In the traffic-domain, a huge amount of information about road user is collected and processed to manage the road traffic in an efficient manner. The sensors, loop detectors and cameras are the commonly used tools and techniques for collecting these information. The information thus collected are sparse, dealing with these information to make certain decision is not as easy as it should be. Therefore, it is necessary to identify what information is needed and how these information can be gathered to provide usefuls services to the users.

The speed of a vehicle depends on the speed of the preceding vehicle. The preceding vehicle may be intentionally driving slowly. It is not clear how to deal with such a situation. If the preceding vehicle is the main source of congestion and hence the cause of other problems (e.g., air pollution), the vehicle behind it is left with no option that just contributing to the problem caused by the preceding vehicle. This problem may possibly require some business intelligence to panalize the intentionally troubling vehicles possibly through communication between vehicles and/or vehicle to infrastructure.

When such communication takes place, the information need to be shared between the communicating parties. It is therefore necessary to identify how privacy sensitive is the information being shared. If the information is privacy sensitive, it has to be dealt with accordingly to avoid any unauthorised manipulation of the information.

7 Conclusions

This paper discusses how a service platform can support communication between vehicles and between vehicles and road infrastructure services as well as third party services. The service platform is based on the concept of service oriented architecture and is aimed at supporting integration of and interoperation between different systems, services and information in road traffic domain. This further allows for providing various user-centric services which help at maximizing user safety, minimizing congestion and environmental pollution, and optimizing the use of road with maximum efficiency. In the current work, we identified different challenges which need to be technically tackled. In our future work, we aim at finding the solution to these challenges and extending the architecture accordingly.

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