Ubiquitous Information Provision in the Vehicle Domain

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***Abstract*— Information sharing and provision in the vehicular field is nowadays a growing research topic in Intelligent Transportation Systems (ITS). Although a lot of work is being carried out in these terms, the most of the approximations are based on local solutions which solve a particular problem. Communication protocols are proposed to exchange information among vehicles in vehicular ad-hoc networks (VANETs), monitoring centres provide information about traffic, advertising mechanisms send location-based notifications about local shops. The system presented in this paper proposes an integrated infrastructure for information sharing in both local and global schemes. Using a novel communication paradigm based on cellular and peer to peer (P2P) networks, traffic information is shared among close vehicles and sent to a core infrastructure for a global processing. This centralized system is able to provide not only traffic events, but also general context-aware information adapted to the user's preferences. The complete design has been developed over a whole prototype, considering both hardware and software requirements.**

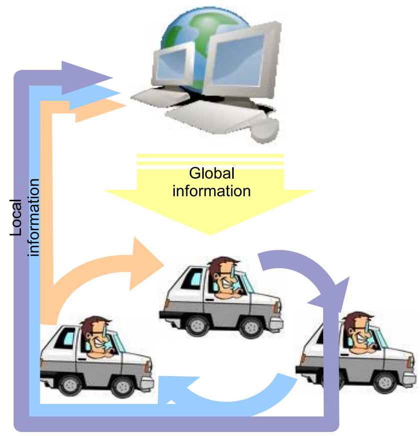

Fig. 1. Providing local and global information to vehicles

I. INTRODUCTION

Maintaining the driver up-to-date about potential collisions is considered as one of the main seeds on vehicular communications developments. Although safety applications have received practically all the attention, new technological improvements and the globalization of services offered in other environments have led to the consideration of new generation services for vehicles. Information provision systems such as meteorology, congestion, or repair services are only the first step. Information from road signs, provision of context-aware information about the traffic state, reception of commercial or cultural information depending on the location and the user's preferences; these are only some examples of new information services for future vehicles [1].

New developments in vehicular safety systems have been centered in communications among vehicles using a decentralized approach. The idea of considering every car as an autonomous router is being considered from several years ago in the vehicular ad-hoc network (VANETs) researching field. This approximation has been specially useful in collision avoidance systems [2]. Using such communication paradigm, vehicles maintain accurate information about a local zone, but as longer the distance between the source and the receiver is, worse is the behaviour of the communication [3]. This makes VANETs to not to be appropriated for services which requires wide range transmissions. Such communication requirements can be solved using cellular networks (CN). Fleet management and monitoring systems use CN to maintain a communication link with vehicles from a central unit [4]. However, these applications are focused on the operator side, not considering the importance of information provision at the vehicle edge and, obviously, using a centralized scheme.

An ideal system would contain both the VANET and CN advantages. Vehicles would cooperate among them transmitting local information, and a centralized infrastructure would give general and processed notifications. Fig. 1 illustrates this idea and, at the same time, the basis of the work presented in this paper. Local traffic events are shared among vehicles and the infrastructure side listens to them in order to maintain a whole view about the road network. Using such approach, a real context-aware information provision technique could be applied, where the infrastructure side is able to adapt the information sent according to the user's preferences.

The information provision solution detailed in this paper comprises a novel communication paradigm based on CN, which is able to work in both vehicle to vehicle and vehicle to infrastructure modes. Peer to peer (P2P) networks have been found as a suitable technology to connect the vehicle with the infrastructure [5], or even create an overlay network in vehicle to vehicle communications [6]. The road side infrastructure receives all the local events and processes them in order to give monitoring capabilities and feedback to the rest of vehicles. The traffic information offered by the system only comprises, nevertheless, part of the available functionality. Through knowledge representation and

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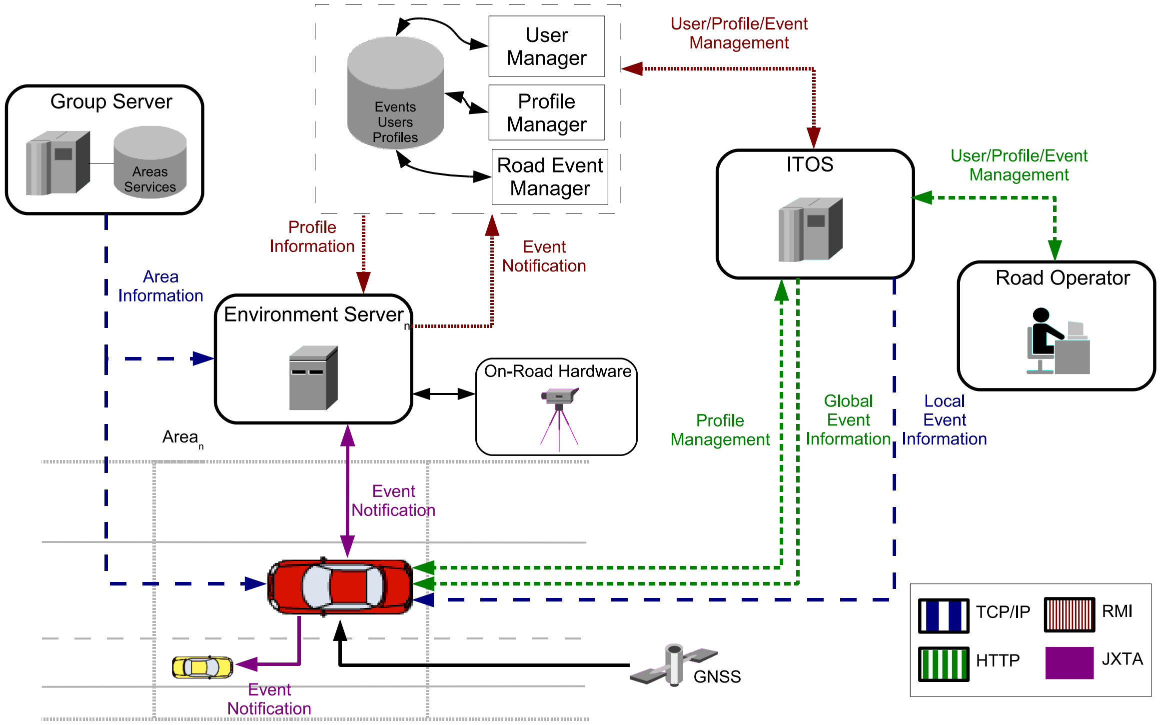

Fig. 2. Overall information management and communication platform

inferring techniques, the traffic environment and the user's preferences have been modeled, and the architecture is able to notify context-aware information about surrounding points of interest (POI). This work integrates the CN-based network infrastructure given in [7] and the technique of provisioning local information given in [8] into a global event notification platform.

The paper is organized as follows. Section II explain the whole information system created for notifying environmental information to drivers. Section III describes the two event notification techniques used by the system. Section IV shows the prototype created, which proves the design feasibility. Finally, Section V concludes the paper.

II. ARCHITECTURE FOR INFORMATION PROVISION AND MANAGEMENT

The main challenge of our work has been the development of a platform which provides ubiquitous services for vehicles in a road environment, with the ability of adapting the provided information according with the user's necessities [9]. Fig. 2 shows the overall architecture of our proposal. Every vehicle travels across road areas with service provisioning capabilities. All coverage areas and its associated services are registered in a global entity called Group Server (GS). Vehicle passes from one coverage area to another through a roaming process aided by a global navigation satellite system (GNSS), in this case the GPS one. GS provides the coverage area geometry to vehicles, so the on-board unit can detect the vehicle is out of the current area and then it asks for the new one. The services conceived in the system have an information nature, so they include safety applications such as break down or repairs notification services, or tourism and travel information about the current place. The methodology carried out follows a publish/subscribe scheme where vehicles subscribe to some services and receive asynchronous notifications [10].

Using a P2P network, by means of the JXTA technology, the physically mapped coverage areas are logically defined through P2P communication groups. This way, every service available in each area uses a P2P group which have to be changed when the vehicle enter in a new area, in order to maintain the service connection. When a vehicle sends a message in such communication system, being subscribed to a notification service, it is received by all the vehicles in the area which are subscribed to the service. However, it must be noted in the figure how an infrastructure entity, placed in every coverage area, listen to all events notified in the zone; this is the Environment Server (ES). ES also plays a forwarder role between vehicles and infrastructure. Because ES is connected to the rest of the road side hardware, it is able to send local notifications to vehicles using a unicast mechanism.

A complete information system at the infrastructure side has been developed as well, as can be seen in the upper part of Fig. 2. The core storage system is implemented using remote objects which are used by the rest of entities. ES notifies received events to this internal logic and the Internet Traffic Operation Server (ITOS) is in charge of managing this information. ITOS provides a web access with a complete view of the events over the road. A web application offers a differentiated access to clients and operators. Operators, unlike clients, have an administration account with management

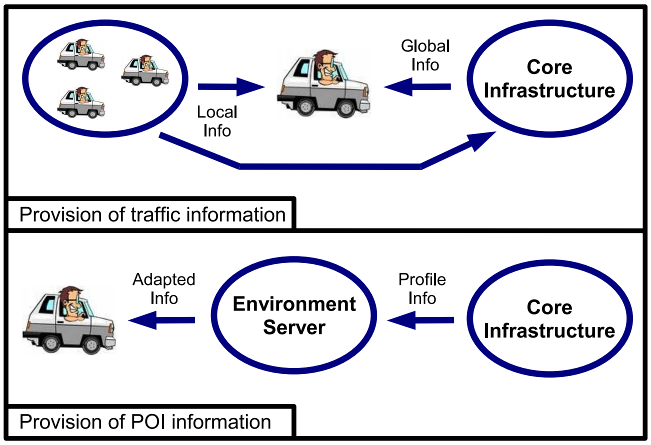

Fig. 3. Information provisioning techniques included in the system

capabilities. The software located in the vehicle, in addition to be able to connect to services offered by GS, downloads traffic notifications about the coverage area in the roaming process from ITOS and draw them over a real map as well.

In order to offer information about the current traffic area in certain services, the environment has been modeled using ontologies with information about the context [8]. This information about every coverage area is saved by the Environment Servers. The user's preferences about the information he is interested in are modeled as profile ontologies located in the core storage system. The user can modify his profile through the web application located at ITOS, and Environment Servers ask for these profiles when it is necessary to perform an inference from the available context information knowledge according to the user preferences. Road operators can manage all the user information through their access to the web application at ITOS.

III. EVENT NOTIFICATION TECHNIQUES AT DIFFERENT LEVELS

In order to clarify the two different information provision methods available in the previous system, they have been simplified in Fig. 3. On one hand, traffic information is provided to vehicles. In order to perform this task, vehicles broadcast traffic events in the coverage area specified by the service used. These messages are received by the centralized entities at the core infrastructure and, as it has been explained, global traffic information is provided to vehicles by means of a web site. The other information provision method is shown at the bottom of Fig. 3. Using such procedure, the driver receives information about points of interest in the zone. The environment server asks the core infrastructure for the driver's profile and provides the user with interesting points of interest, as it is described in the previous section.

This way, there are three levels of information processing:

1. Vehicle level. Vehicles generate traffic events which receive other vehicles in a bounded area. These vehicles have to be subscribed to traffic information services.
2. ES level. Environment servers infer interesting information about near points of interest and provide it to vehicles subscribed to POI information services.
3. Core infrastructure level. The internet traffic operation server provides processed information about traffic using a web site frontend. This entity sends also traffic incidences about a coverage area to vehicles which perform a roaming to this one.

IV. PROTOTYPE DETAILS

The complete system has been developed using a real vehicle, real hardware for the infrastructure, and implementing all the necessary software. The vehicle used in the operation tests has been a widely sensorized car designed at the university of Murcia [11]. This vehicle uses a Single Board Computer (SBC) of VIA as on-board computer. It uses a Linux Fedora Core 4 operating system and a Java Virtual Machine 1.5. The computer is connected to the sensors installed in the vehicle (GPS, odometry…), a LCD monitor installed in the dashboard, and the rest of peripherals. All this hardware comprises the on-board unit (OBU). We have implemented the Environment Server, and its instances (one per coverage area) are executed over a Linux-based PC. We have set up a RFID reader which is connected with the corresponding ES, in order to test the provision of POI information [8]. The reader terminal detects the vehicle presence through a tag located in the windscreen, and notify such event to ES. The Group Server and the Internet Traffic Operation Server have been developed and then installed over a high performance server, in order to cover high rates of queries. Both the ES and GS are executed over an AMD Opteron multiprocessor computer.

The web application located at ITOS contains a graphical tool to monitor the road events over a real map, and manage the registered users and their likes for information reception. The OBU contains a software platform for installing on-board applications [12]. One of them is Message Console, which appears in Fig. 4. This application is able to use the information services offered by the explained system. The user connects to the services he is interested in using the buttons available on the right part of the window. When the activated services are available in the current coverage zone, their corresponding images appear below and it is possible to send and receive events. The central part of the window shows all the received messages. In this example, the vehicle has received information about hotels and cinemas which match the user's requirements. The service which provides such information is called "On Road Information". It uses the RFID system to locate the vehicle in a concrete place. When ES receives the presence notification it asks the core infrastructure for the user's profile, and then infers interesting information for the user by means of its local database about the environment. Finally, ES sends this information to the vehicle, including the matching rate for every environment concept notified. In the example, the hotel which better suits the user's preferences is "AC Elche", with a matching rate of 43 %.

Fig. 4 shows as well the navigation capabilities of the on-board software, which marks the places where an incidence

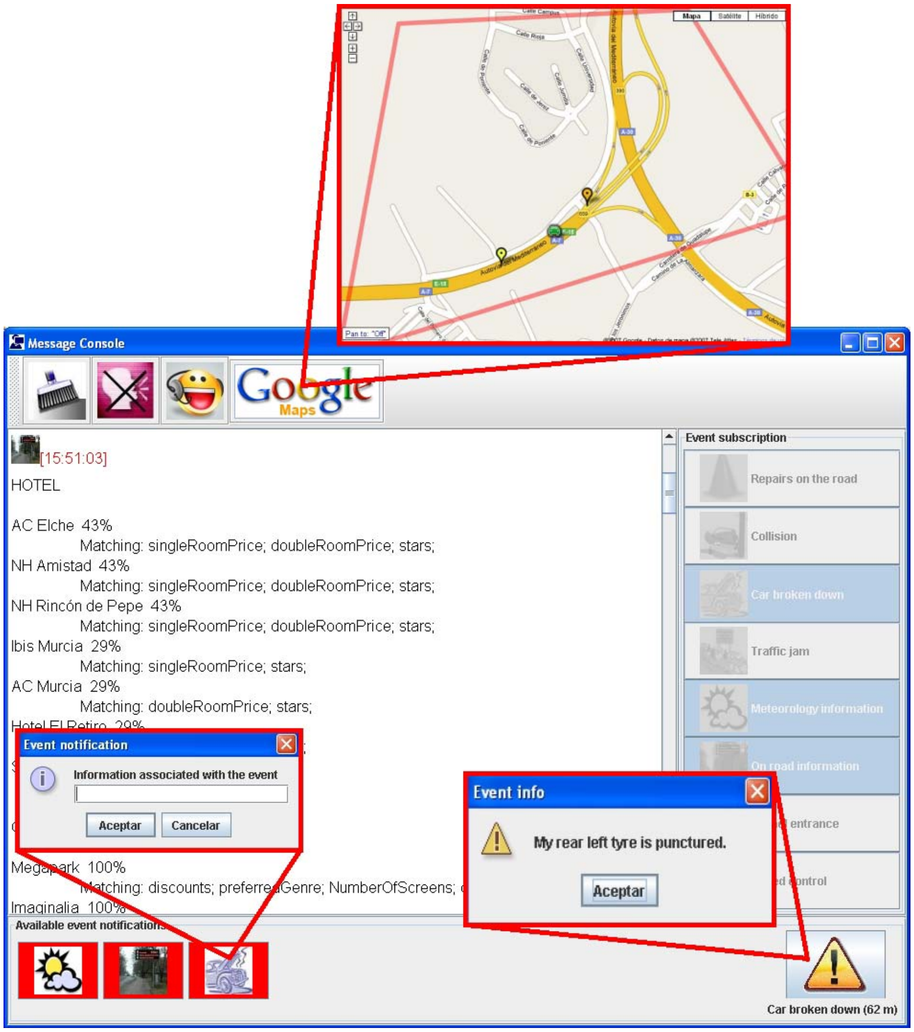

Fig. 4. On-board software for context-aware information sharing

has occurred. Because the vehicle receives the local road problems in the roaming process, and listen to the new ones, the software draws not only the current vehicle position but also it can plot road events in the area. The polygon which covers the current coverage area is also depicted using a light red line. When the vehicle is close to a road event, the application shows a warning about it and emits a spoken alert. In the example, a warning about the proximity of a breakdown on the road has been raised. The flat tyre event has been artificially generated at the ATOS web site in order to test the provision of traffic information from the infrastructure side. Numerous tests shows, however, the correct operation of the network when a close vehicle transmit a traffic event [7].

V. CONCLUSIONS

The paper proposes a novel ubiquitous environment for the road domain. Vehicles can subscribe to information services, in order to receive local information about traffic events occured in the environment. The road side infrastructure provides these services at each coverage area, whose geometry bounds the transmission of messages over the CN and P2P based network. A global information system has been designed to process all traffic events received from vehicles. This core infrastructure provides a web access to users, where the state of roads can been consulted. Contextual information about interesting points of interest is also provided to users. To perform this task, environmental information and driver's profiles have been modeled as onlogies. A local server is in charge of maintaining the local knowledge and asking for the driver's profile in order to infer interesting information for users inside the area.

The whole system has been developed by means of a prototype for both the vehicle and the infrastructure sides, and a real scenario has been mounted. In the tests the on-board unit successfully receives events about traffic incidences and points of interest information from the road side, which is adapted to the user's preferences.

Future lines include further researching in the vehicular network used, including new tests with recent improvements in cellular networks. WiMAX technology is also planned to be used, in order to compare its performance with CN. The core system located at the infrastructure side is currently being updated with new capabilities, in order to offer more specific information about the road state.

ACKNOWLEDGEMENTS

The authors would like to thank the Spanish Ministerio the Educación y Ciencia for sponsoring the research activities under the grant AP2005-1437, in frames of the FPU program. Special thanks as well to the Spanish Ministerio the Fomento for its continuous support in vehicular researching.

REFERENCES

[1] S. Fuchs, S. Rass, B. Lamprecht and K. Kyamakrya, "Context-Awareness and Collaborative Driving for Intelligent Vehicles and Smart Roads," *1st Int'l Workshop ITS Ubiquitous ROADS* (UBI-ROADS 2007), *IEEE Global Information Infrastructure Symp.* (GIIS 2007), 2007.

[2] J. Ueki, S. Tasaka, Y. Hatta, and H. Okada, Vehicular-Collision Avoidance Support System (VCASS) by Inter-Vehicle Communications for Advanced ITS, *IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences*, vol. E88-A, no. 7, 2005, pp. 1816–1823.

[3] S. Biswas, R. Tatchikou, and F. Dion, Vehicle-to-Vehicle Wireless Communication Protocols for Enhancing Highway Traffic Safety, *IEEE Communications Magazine*, vol. 44, no. 1, 2006, pp. 74–82.

[4] B. Hoh, M. Gruteser, H. Xiong and A. Alrabady, Enhancing Security and Privacy in Traffic-Monitoring Systems, *IEEE Pervasive Computing*, vol. 5, no. 4, 2006, pp. 38–46.

[5] L, Baresi, C. Ghezzi, A. Miele, M. Miraz, A. Naggi and F. Pacifici, "Hibrid service-oriented architectures: a case-study in the automotive domain," *Proc. 5th Int'l Workshop Software Engineering and Middleware* (SEM'05), 2005, pp. 62–68.

[6] J. Rybicki, B. Scheuermann, W. Kiess, C. Lochert, P. Fallahi and M. Mauve, "Challenge: Peers on Wheels - A Road to New Traffic Information Systems," *Proc. 13th Ann. ACM Int'l Conf. Mobile Computing and Networking* (MobiCom 2007), 2007, pp. 215–221.

[7] J. Santa and A.F. Gomez-Skarmeta, "Architecture and evaluation of a unified V2V and V2I communication system based on cellular networks," *Computer Communications*, in press.

[8] J. Santa, A. Muñoz, and A.F.G. Skarmeta, "A Context-Aware Solution for Personalized En-route Information Through a P2P Agent-Based Architecture," *Proc. 2007 Int'l Conf. Computational Science and Its Applications* (ICCSA 2007), LNCS 4707, Springer, 2007, pp. 710–723.

[9] I.Y.L. Chen, S.J.H. Yang, and J. Zhang, "Ubiquitous Provision of Context Aware Web Services," *Proc. 2006 Int'l Conf. Services Computing* (SCC 2006), 2006, pp. 60–68.

[10] G. Cugola, and H. Jacobsen, Using Publish/Subscribe Middleware for Mobile Systems, *ACM SIGMOBILE Mobile Computing and Communications Review*, vol. 6, no. 4, 2002, pp. 25–33.

[11] A.F.G. Skarmeta, H. Martínez, M. Zamora, F. Cesareo and L.M. Tomás, Mimics: Exploiting Satellite Technology for an Intelligent Convoy, *IEEE Intelligent Systems*, vol. 17, no. 4, 2002, pp. 85–88.

[12] J. Santa, B. Úbeda, A.F.G Skarmeta, "A Multiplatform OSGi Based Architecture for Developing Road Vehicle Services," *Proc. 4th Ann. IEEE Consumer Comm. and Networking Conf.* (CCNC 2007), 2007, pp. 706–710.