A Realistic Prototype for Automatic Accident Detection and Assistance through Vehicular Networks

Manuel Fogue, University of Zaragoza, Spain
Piedad Garrido, University of Zaragoza, Spain
Francisco J. Martinez, University of Zaragoza, Spain
Juan-Carlos Cano, Universitat Politècnica de València, Spain
Carlos T. Calafate, Universitat Politècnica de València, Spain
Pietro Manzoni, Universitat Politècnica de València, Spain

The symbiosis between communication technologies and vehicles offer a priceless opportunity to improve assistance to people injured in traffic accidents, providing information about the incident to reduce the response time of emergency services. Determining more accurately the required human and material resources for each particular accident could significantly reduce the number of victims. This paper presents our novel system prototype especially designed to detect and provide faster assistance for traffic accidents, thereby minimizing the consequences on the passengers' health. The proposed system requires each vehicle to be endowed with an On-Board Unit responsible for detecting and reporting accident situations to an external Control Unit that estimates its severity, allocating the necessary resources for the rescue operation. The development of our prototype based on off-the-shelf devices, and its validation at the Applus+ IDIADA Automotive Research Corporation facilities, shows that our system could notably reduce the time needed to alert and deploy the emergency services after an accident takes place.

Introduction

During the last decades, the total number of vehicles around the world has experienced a remarkable growth, making traffic density higher and increasing the drivers' attention requirements. The immediate effect of this situation is the dramatic increase of traffic accidents on the road, representing a serious problem in most countries. As an example, 2,478 people died on Spanish roads in 2010, which means one death for every 18,551 inhabitants [1].

Numerous efforts have been undertaken by automobile manufacturers to reduce road casualties, mainly focused on both active and passive safety systems. These initiatives have managed to increase traffic safety, achieving a reasonable reduction of road deaths. However, accidents can still occur, and a quicker response from emergency services could significantly decrease both the amount of injured and dead passengers, as well as the impact and severity of such accidents.

The European Commission is currently funding several projects under the i2010 Intelligent Car Initiative, which promotes several efforts toward new safety systems. Cooperative Systems using *vehicle-to-vehicle* (V2V) communications are now considered necessary to accomplish these objectives, and will play an increasing role in the *Intelligent Transportation Systems* (ITS) area. Most ITS applications, such as road safety, fleet management, and navigation, will rely on information and communication technologies between the vehicle and the roadside infrastructure (V2I), or between vehicles (V2V).

In this paper we present our prototype architecture called e-NOTIFY, a novel proposal designed to improve the chances of survival for passengers involved in car accidents. The proposed system offers automated detection, reporting, and assistance of passengers involved in road accidents by exploiting the capabilities offered by vehicular communication technologies. Our proposal does not directly focus on reducing the number of accidents, but on improving post-collision assistance with fast and efficient management of the available emergency resources, increasing the chances of recovery and survival for people injured in traffic accidents.

Motivation

When a traffic accident takes place, assisting injured passengers as soon as possible is crucial to minimize the negative effects on their health. Mortality from traffic accidents can be classified in three different stages [2]:

- First phase: It involves casualties in the first few minutes or seconds after the accident (about 10% of all deaths).
- Second phase: The so-called *Golden Hour*, as it usually occurs during the first hour after the accident. It causes the highest mortality, i. e., 75% of all deceases. It is the phase in which the highest death rate can be avoided by proper initial health care.
- Third phase: It happens days or weeks after the traumatic incident, causing 15% of mortality. It takes hard work and

a high amount of resources to reduce mortality in this phase.

As can be observed, the phase where more benefits can be achieved by reducing rescue response time is the second one. A fast and efficient rescue operation during the hour after a traffic accident significantly increases the probability of survival of the injured, and reduces the injury severity.

For a noticeable reduction in rescue time, two major steps must be taken: (i) fast and accurate accident detection and reporting to an appropriate Public Safety Answering Point (PSAP), and (ii) fast and efficient evacuation of occupants trapped inside a vehicle. The first of these objectives can be accomplished by using telecommunication technologies incorporated into the automotive world. There have been many advances in the development of technologies for communication between vehicles (V2V), also known as (VANETs or *Vehicular Ad hoc NETworks* [3]), offering support for cooperative security applications between vehicles. In fact, the 802.11p working group recently approved the IEEE 802.11p standard [4], providing a viable solution for inter-vehicular security applications. This technology has been already studied to increase traffic safety in dangerous areas such as intersections [5].

However, accomplishing the second goal is becoming harder and harder every year. Studies conducted by the ADAC German automobile club [6] have proved that the rescue operation of injured people from a vehicle takes longer the more recent the vehicle is. This effect is clearly visible in Figure 1, where the impact of the year of manufacture of the vehicle in the rescue speed is shown. We observe that the increase of security equipment that makes vehicles safer also implies more complexity for the emergency teams. From the *golden hour* perspective, this is a serious threat to the successful rescue of injured persons.

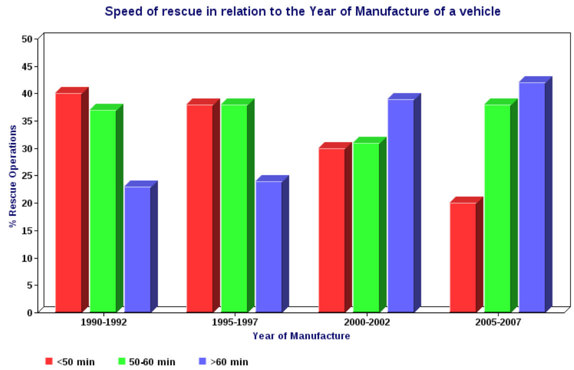

Figure 1 *Impact of the year of manufacture of the vehicle in the rescue speed [6].*

Increasing the amount of information available about the accident and the vehicle involved could definitely contribute to the second goal [7]. In fact, the effectiveness of the assistance to passengers involved in a traffic accident could be significantly improved if emergency services had available relevant information on the conditions under which the accident happened before moving to the area of the accident. As shown in Figure 2, up to 63% of all problems that rescue teams can find when facing an accident could be reduced by providing emergency services with additional information. This extra information, obtained from sensors inside the vehicle, would be used to estimate the severity of the occupants' injuries. Also, having more information would allow determining the optimal set of human and material resources to be sent to the accident location, with the consequent assistance quality improvement.

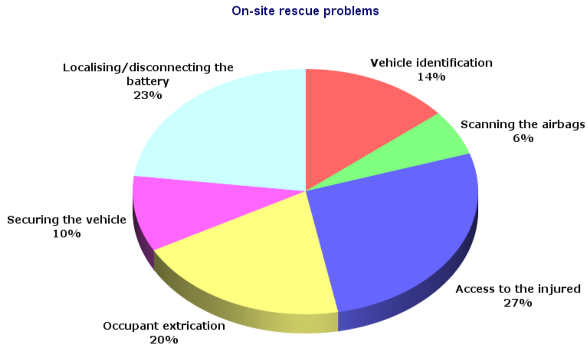

Figure 2 *Main rescue problems at the accident site [6].*

Related projects

A number of research projects headed by different research institutes and car manufacturers around the world have been focusing on inter-vehicle communication systems. Some of the larger projects related to our e-NOTIFY system are listed below:

- *COMeSafety2* [8]: The COMeSafety2 project proposal aims at coordinating the activities towards the realization of cooperative systems on European roads, focusing on all issues related to vehicle-to-vehicle and vehicle-to-infrastructure communications. Its main goal consists of developing a European set of standards to support wide implementation and deployment of cooperative Intelligent Transport Systems.
- *eCall* [9]: The eCall system has been designed to improve transportation safety, providing rapid assistance to people involved in a collision anywhere in the European Union. A collision activates an emergency voice call to be established via the cellular network to local emergency agencies. In addition, e-Call transmits a *Minimum Set of Data* (MSD), including key information about the accident such as time, location and vehicle description. It is supposed that the eCall system will be operative by 2015.
- *OnStar* [10]: It is an in-vehicle safety and security system created by General Motors (GM) for on-road assistance, which resembles the European eCall project. A collision activates an emergency voice call to report key information about the accident.

The most similar projects to e-NOTIFY are both the eCall and the OnStar projects, which are expected to be manually activated, or using the in-vehicle sensors for airbag deployment. However, our proposal goes one step beyond their aims. We are developing an autonomous intelligent system that allows automatically adapting the required rescue resources to each particular accident, allowing the rescue staff to work far more efficiently, and reducing the time associated to their tasks.

e-NOTIFY System: Architecture Overview

Figure 3 presents the basic structure of the e-NOTIFY system. Our proposed system consists of several components with different functions. Firstly, the vehicles should incorporate an On-Board unit (OBU) responsible for detecting accidents and communicating about dangerous situations. Next, the notification of the detected accidents is made through a combination of both V2V and V2I communications. Finally, the destination of the information is the Control Unit (CU) that will handle the warning notification, estimating the severity of the accident and communicating the incident to the appropriate emergency services.

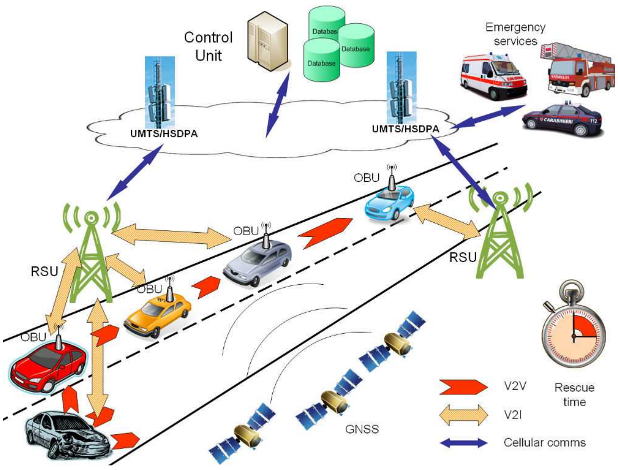

Figure 3 *e-NOTIFY architecture based on the combination of V2V and V2I communications.*

The OBU definition is of utmost importance for the proposed system. This device must be technically and economically feasible, as its adoption in a wide range of vehicles could become massive in a near future. In addition, this system should be open to future software updates. Although the design of the hardware to be included in vehicles initially consisted of special-purpose systems, this trend is heading towards general-purpose systems because of the constant inclusion of new services.

The information exchange between the OBUs and the CU is made through the Internet, either through vehicles providing Internet access (via UMTS, for example), or by reaching infrastructure units (*Road-Side Units*, RSU) that provide this service. If the vehicle does not get direct access to the CU on its own, it can generate messages to be broadcast by nearby vehicles until they reach one of the aforementioned communication paths. These messages, when disseminated among the vehicles in the area where the accident took place, also serve the purpose of alerting drivers traveling to the accident area about the state of the affected vehicle, and its possible interference on the normal traffic flow.

The goal of our proposal is to provide an architecture that allows: (i) direct communication between the vehicles involved in the accident, (ii) automatic sending of a data file containing important information about the incident to the Control Unit, and (iii) a preliminary and automatic assessment of the damage of the vehicle and its occupants, based on the information received from the involved vehicles, and a database of accident reports. According to the reported information and the preliminary accident estimation, the system will alert the required rescue resources to optimize the accident assistance.

On-Board Unit (OBU) Design

The main objective of the e-NOTIFY OBU lies in obtaining the available information from sensors inside the vehicle to determine when a dangerous situation occurs, and reporting that situation to the nearest Control Unit, as well as to other nearby vehicles that may be affected.

OBU Internal Structure

Figure 4 shows the e-NOTIFY OBU system, which relies on the interaction between sensors, the data acquisition unit, the processing unit, and wireless interfaces:

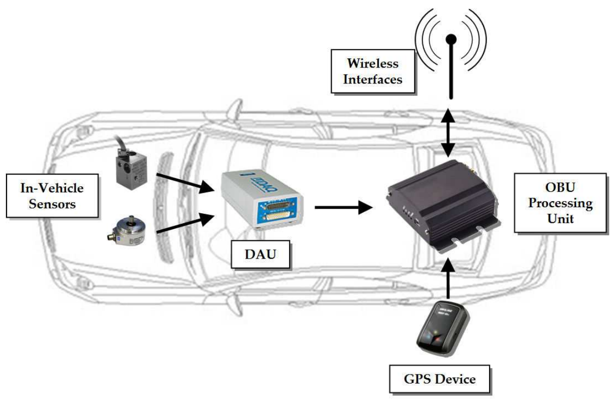

Figure 4 *OBU structure diagram.*

- *In-vehicle sensors*. They are required to detect accidents and provide information about its causes. Accessing the data from in-vehicle sensors is possible nowadays using the On-Board Diagnostics (OBD) standard interface [11], which serves as the entry point to the vehicle's internal bus. This standard is mandatory in Europe and USA since 2001. This encompasses the majority of the vehicles of the current automotive park, and the percentage of compatible vehicles will keep growing as very old vehicles are replaced by new ones.

- *Data Acquisition Unit (DAU)*. This device is responsible for periodically collecting data from the different sensors available in the vehicle (airbag triggers, speed, fuel levels, etc.), converting them to a common format, and providing the collected data set to the OBU Processing Unit.
- *OBU Processing Unit*. It is in charge of processing the data from sensors, determining whether an accident occurred, and notifying dangerous situations to nearby vehicles and to the Control Unit. The information from the DAU is gathered, interpreted and used to determine the vehicle's current status. This unit must have access to a positioning device (such as a GPS receiver), and also have access to different wireless interfaces, thereby enabling communication between the vehicle and the remote control center.

Accident Detection Algorithm

The first goal of our OBU consists of determining when a dangerous accident occurs. In the traffic accidents domain, there are two main events that could cause severe damage to the passengers in a vehicle: rollovers (overturns) and strong impacts. We are currently working with the Applus+ IDIADA Automobile Research Corporation [12] to develop a realistic accident detection algorithm based on information which characterizes different types of accident.

Crash tests held by IDIADA collect a huge amount of information about the collision (10,000 samples per second) which is unfeasible to be handled in real-time, thus it must be processed off-line after the accident. Nevertheless, for a really useful system, data must be processed in the moment of the accident to reduce the assistance time and the effects of the collision on the passengers. Moreover, the equipment used by IDIADA to record all this information is not affordable in a standard vehicle. Therefore, our detection system should be based on an affordable on-line system, but still accurate to detect when an accident occurs. So, e-NOTIFY OBUs use a reduced sampling frequency compared to the configuration under IDIADA tests. The new sampling frequency is selected so that it is possible to handle it in real-time, while being precise enough to classify the different types of accident pulses. Our experiments showed that about 100 measurements per second are adequate to achieve a trade-off between accuracy and real-time processing.

When we are trying to detect an accident, a rollover in a vehicle is quite simple to recognize using a horizontal tilt sensor, since measurements deviating more than 90 degrees from the horizontal, or a constant value over 45 degrees (partial rollover), indicate that the vehicle overturned and needs to be rescued.

The interpretation of acceleration values is more complicated. The straightforward approach to classify collisions would consist of defining a series of acceleration thresholds. Nevertheless, this simple method is not valid for all tested situations, as shown in Figure 5. The graph contains different pulses corresponding to front crashes with different severities. As shown, the peak acceleration recorded in the minor accident exceeds the maximum value registered in the severe collision, although the duration of the pulse is much smaller. So, it is clear that using simple acceleration thresholds to distinguish the acceleration pulses is not enough, and both their amplitude and duration should be considered to better estimate the severity of accidents.

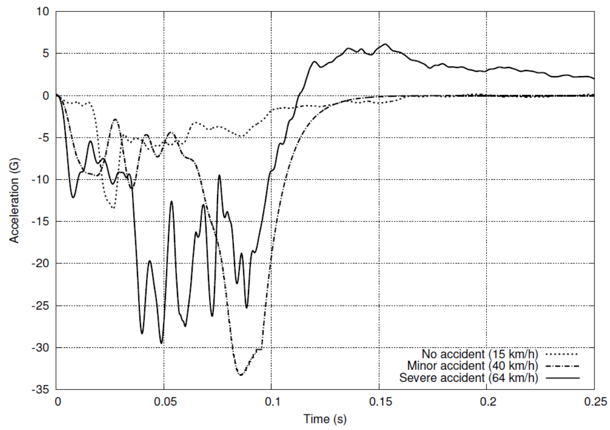

Figure 5 *Acceleration pulses for different front crash ratings. Data provided by Applus+ IDIADA Corporation [12].*

To take into account both the amplitude and duration of the pulse, our e-NOTIFY system uses the area that the pulse forms with the X axis, which can be obtained applying the integral of the function. Therefore, we will make use of the integral value of the function to classify acceleration pulses and determine the preliminary severity of an impact.

OBU Design under the OSGi Environment

The e-NOTIFY OBUs make use of the OSGi (Open Services Gateway initiative) standard [13], which enables the development of applications (in the form of *bundles* or modules for deployment) that can be installed, started, stopped, updated and uninstalled remotely without rebooting the system. Many car manufacturers have included the OSGi specification in their *Global System for Telematics* (GST) specification. Hence, it has been chosen to be implemented in the e-NOTIFY system since OSGi is becoming the *de facto* standard for vehicular network systems.

In the OSGi environment, a bundle is an application packaged in a JAR (Java ARchive) which is deployed in an OSGi platform. Therefore, the applications to be executed by the OBUs must be programmed in the Java language, and packaged in a JAR file that allows deployment as a module in the system. The inclusion of new services may be performed using a similar procedure, obtaining a highly scalable and updateable architecture.

Control Unit (CU) Design

The Control Unit (CU) is associated to the response center in charge of receiving notifications of accidents from the OBUs installed in vehicles. In particular, the Control Unit is responsible for dealing with warning messages, retrieving information from them, and notifying the emergency services about the conditions under which the accident occurred.

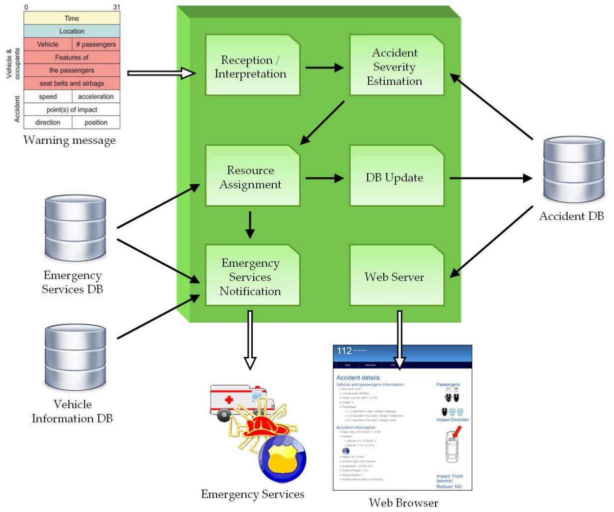

Figure 6 *Control Unit modular structure.*

CU Internal Structure

Figure 6 shows the modules included in the Control Unit to achieve all its objectives within the e-NOTIFY system:

- *Reception/interpretation module*. The first step for the CU is to receive a warning message from a collided vehicle, and so there must be a module waiting for the arrival of messages and obtaining their different fields.
- *Accident severity estimation module*. When a new accident notification is received, this module will determine how serious the collision was, and the severity of the passengers' injuries.
- *Resource assignment module*. After deciding the severity of the accident, an additional module is used to define resource sets adapted to the specific situation.
- *Database update module*. The data collected from the notified accident are stored into the existing database of previous accidents, increasing the knowledge about the accident domain.
- *Web Server module*. The Control Unit incorporates a Web Server to allow easy visualization of the historical information recorded and the current accident situations requiring assistance. We chose a web interface in order to increase user friendliness and interoperability.
- *Emergency services notification module*. When the information has been correctly managed, the notification module sends messages to the emergency services including all the information collected, the estimated severity, the recommended set of resources, as well as additional information about the vehicles involved in the collision (for preliminary planning of the rescue operation). The information about vehicles consists of standard rescue sheets, which highlight the important or dangerous parts of a specific vehicle that should be taken into account during a rescue operation: batteries, fuel tanks, etc., as shown in Figure 7.

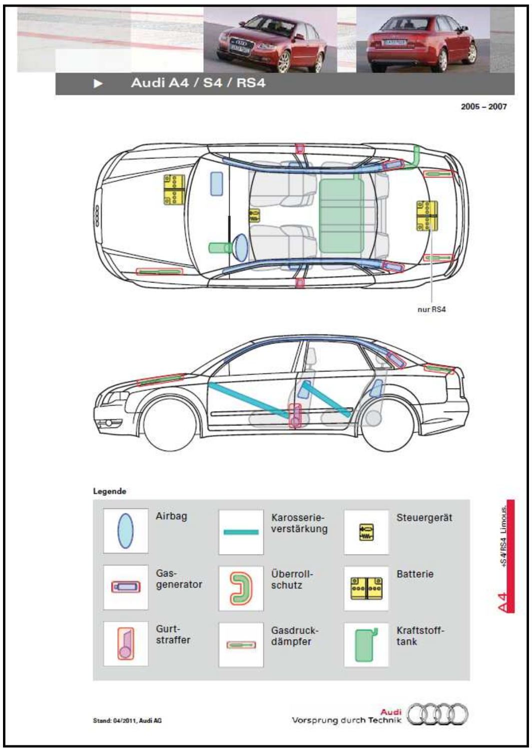

Figure 7 *Example of standard rescue sheet.*

The Control Unit makes use of three different databases to handle accident notifications. The accident database contains historical data from past accidents detected by the system, and it is used to build the estimation models that predict the severity of new accidents. The vehicle information database provides, for each vehicle, available information about rescue procedures, dangerous components inside each car, etc. Finally, the emergency services database includes information about the rescue services available in the area of influence of the CU in order to determine the emergency services needed for each specific accident.

Accident Severity Estimation

After receiving an accident notification, the Control Unit must determine the severity of the traffic accident to adjust the available resources to each situation. In particular, the questions that must be answered to obtain useful information are: (i) How damaged are the vehicles involved in the accident? and (ii) How severe are the injuries suffered by the passengers? The first question will determine the need of machinery such as cranes to restore normal traffic flow, or the likability for the vehicle to catch fire and cause additional dangerous situations. The second one is related to the health equipment and vehicles necessary to increase the probability of survival of the vehicle occupants.

Developing a useful algorithm to estimate accident severity needs historical data to ensure that the criteria used are suitable and realistic. The National Highway Traffic Safety

Administration (NHTSA) maintains the General Estimates System (GES) [14], a database with information about traffic accidents which began operating in 1988. The data for this database is obtained from a sample of Police Accident Reports (PARs) collected all over the USA roads. This database includes information about the crash characteristics and environmental conditions at the time of the accident, vehicles and drivers involved in the crash, and people involved in the collision.

Using the data contained in the GES database, we classify the damage in vehicles in three categories: *minor*, *moderate*, and *severe damage*, depending on whether the vehicle can be driven safely or not. Focusing on passenger injuries, we also use three different classes to determine their severity: *no injury*, *non-incapacitating injury*, and *incapacitating or fatal injury*.

The data mining classification algorithms used to estimate the accident severity were built using the Weka open-source data mining package [15]. By using data mining classification algorithms based on Bayesian networks and the K2 search algorithm [16], trained with the values from previous accidents in the GES database, we are able to generate classification models that correctly estimate the accident severity more than 75% of the cases. Therefore, these estimations may be used to adapt the resources to the conditions of the accident.

Prototype Implementation and Validation

We built a prototype for the e-NOTIFY system using off-the-shelf devices, allowing fast development and reduced cost.

OBU Prototype

The Data Acquisition Unit in our initial prototype is built using an ARM microcontroller programmed to periodically collect data from in-vehicle sensors. Basically, these sensors are accelerometers and gyroscopes that indicate the severity of the impacts received by the automobile or the occurrence of a rollover that might endanger the integrity of the occupants. Communication between the microcontroller and the Processing Unit is done by sending UDP packets through an Ethernet interface.

The OBU Processing Unit in our prototype is a general-purpose Asus Eee PC netbook, equipped with solid state disk (SSD) to minimize the possibility of damage due to impact in crash tests. The vehicle position and speed are obtained using a GPS device accessible using Bluetooth.

CU Prototype

The Control Unit prototype for the initial tests was built using common software components, allowing fast prototyping with little cost.

The reception/interpretation module was implemented using the Java programming language. This module acts as a concurrent server, creating different execution threads to handle each message received, which allows exploiting multiprocessor or multicomputer architectures.

Databases are managed using the MySQL relational database management system. MySQL was selected because of its scalability and easy integration with the rest of components of the Control Unit.

The Web server for the visualization module is Apache. To support dynamic content, we use the PHP (Hypertext Preprocessor) technology, which is easily integrated into Apache. By combining these technologies and MySQL, users can visually check the system status, as shown in Figure 8.

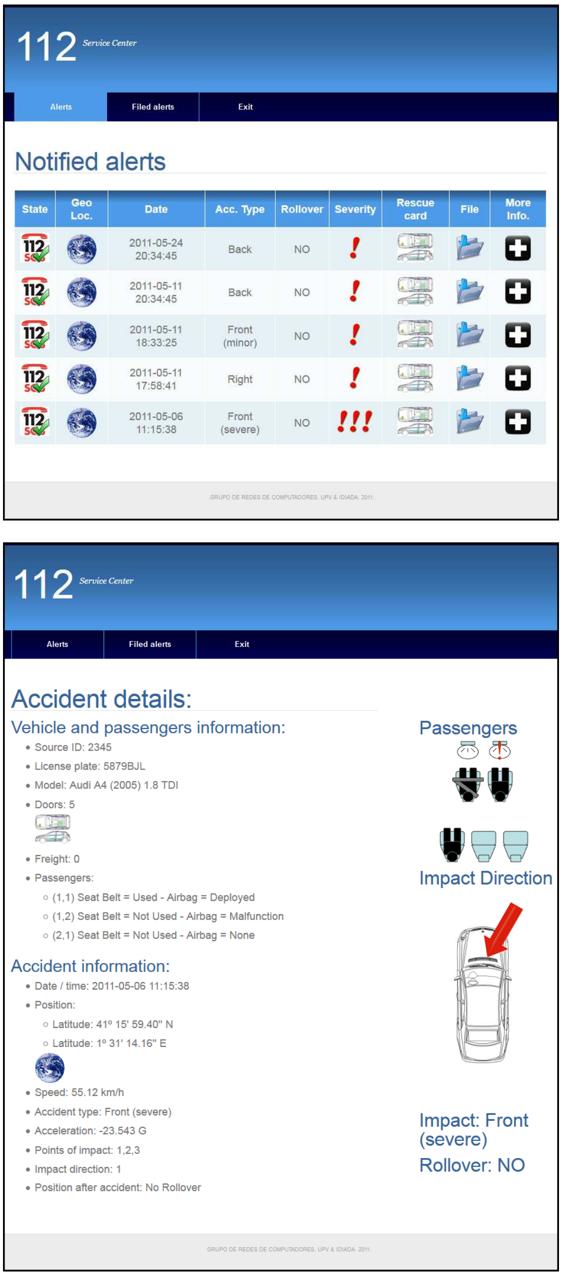

Figure 8 *Web interface screenshots with information about notified accidents.*

Prototype Validation

Our prototype was validated at the Applus+ IDIADA [12] Passive Security Department facilities in Santa Oliva (Tarragona, Spain). These facilities house one of the most sophisticated crash test laboratories in the world, and constitute an official center for approval under the Euro NCAP program.

Due to the cost of using real vehicles in the collision experiments, the e-NOTIFY prototype tests were performed using a platform (known as “sled”) that moves on rails in order to collide against a series of metal bars that simulate the deformation suffered by a vehicle body to absorb the impact. The speed of the stroke and the configuration of bars used in the test determine, respectively, the kind of accident detected and the segment the simulated vehicle belongs to (family car, off-road, etc.). Tested speeds are determined by European standards and vary from 10 km/h to 64 km/h to represent different accident severities.

Figure 9 shows the sled used in the tests. Validation experiments consisted of front, side, and rear-end crash tests, accounting for both accident and no accident situations. The classification of the severity of the collision is dictated by the parameters used in Applus+ IDIADA in automotive standard tests. The specific tests performed during the validation phase appear in Table 1.

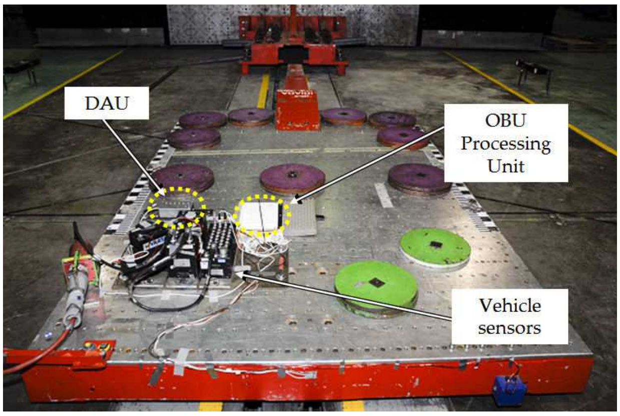

Figure 9 *Sled with the e-NOTIFY prototype installed before a crash detection test.*

Accident type	Vehicle segment	Accident severity	Pulse duration	Accel.
Front accident	Large Family Car	Severe acc.	110 ms	23–28 G
	Large MPV	Minor acc.	100 ms	15–21 G
	Small Family Car	No acc.	110 ms	4–9 G
Side accident	Small Off-Road 4x4	Accident	90 ms	14–21 G
	Supermini	No acc.	90 ms	3–6 G
Rear-end accident	Small MPV	Accident	110 ms	5–7 G
	Supermini	No acc.	70 ms	2–6 G

Table 1 *Validation tests performed on the e-NOTIFY system*

The test system included an external computer receiving regular information from the sled (via a wireless network) of the measurements recorded by the OBU to ensure the proper behavior of the sensor reading module, along with a Control Unit in charge of receiving alert messages and applying the corresponding algorithms. The real trials were performed with two different objectives: proving that the OBU prototype was solid enough to resist a dangerous impact and thus it could continue working after the accident, and also ensuring the proper function of the system under a realistic crash situation.

All the tests produced very positive results, since the OBU did not suffer from noticeable damage even in the strongest impacts. The experiment helped to show that the OBU was able to correctly detect both the magnitude and direction of the impact. Figure 10 summarizes how acceleration pulses were handled by the e-NOTIFY system in two of the experiments. As shown, using a reduced sampling frequency we obtain a similar pulse shape with less than 10% variation in the integral value (approximated by the sum of smaller rectangle areas) compared to the area obtained using the highest sampling frequency.

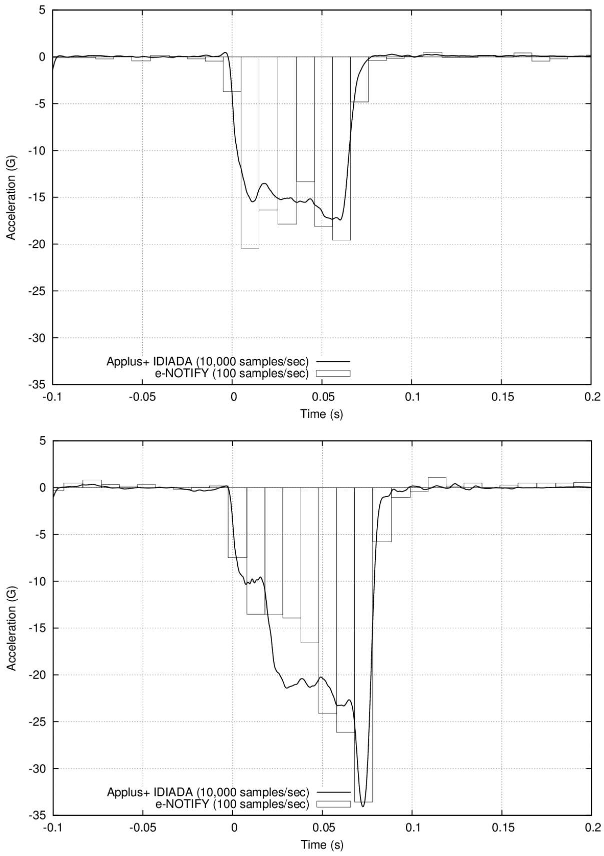

Figure 10 *Acceleration pulses collected by Applus+ IDIADA compared to the samples obtained by the e-NOTIFY system in the same experiments: front minor accident (top), and front severe accident (bottom).*

In addition, the OBUS generated an appropriate warning message from the sensor data and send it using UMTS technology to the Control Unit in all accident configurations, as shown in Figure 11. The latter properly processed the accident details, generating a correct estimation of the severity of the accident.

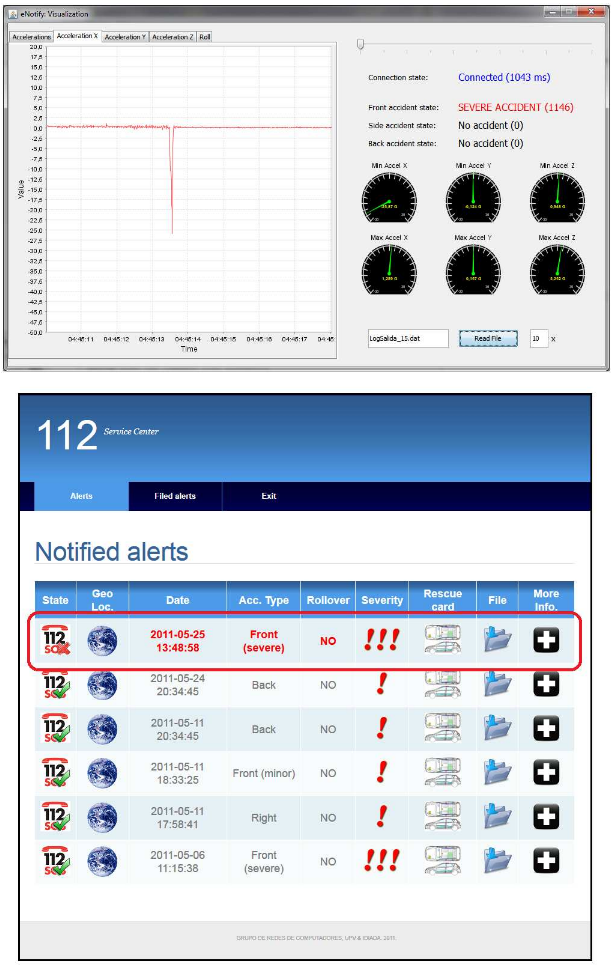

Figure 11 *Images of the crash test results: Accident pulse recorded by the OBU (top), and the same accident notified and received by the CU (bottom).*

Conclusions

In this paper we presented the e-NOTIFY system, which allows fast detection of traffic accidents, improving the assistance to injured passengers by reducing the response time of emergency services through the efficient communication of relevant information about the accident using a combination of V2V and V2I communications. The proposed system requires installing On-Board Units in the vehicles, in charge of detecting accidents and notifying them to an external Control Unit, which will estimate the severity of the accident and inform the appropriate emergency services about the incident. This architecture replaces the current mechanisms for notification of accidents based on witnesses, who may provide incomplete or incorrect information after a much longer time. The development of a low-cost prototype shows that it is feasible to massively incorporate this system in existing vehicles. We validated our prototype at the Passive Security Department of Applus+ IDIADA Corporation, and showed how it can successfully detect traffic accidents, reporting all the detailed information to a Control Alert System on time. Future work in this area includes deploying the system in a real environment with the OBUs installed in real vehicles to check the system behavior when moving at high speeds.

References

[1] Dirección General de Tráfico (DGT) Web Site. (2011, Sep. 15). The main statistics of road accidents in Spain, 2010 [Online]. Available: http://www.dgt.es/portal/es/seguridad_vial/estadistica

[2] Real Automóvil Club de Cataluña (RACC). (2011, Mar. 9). RACC Press Note - Rescue Sheet [Online]. Available: http://www.hojaderescate.es/racc/public/cas/pdf/NP_FULLRESCAT_CASTE.pdf

[3] H. Hartenstein and K. Laberteaux, "A tutorial survey on vehicular ad hoc networks," *IEEE Communications Magazine*, vol. 46, no. 6, pp. 164–171, June 2008.

[4] IEEE 802.11 Working Group, "IEEE Standard for Information Technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 6: Wireless Access in Vehicular Environments," July 2010.

[5] L. Le, A. Festag, R. Baldessari, and W. Zhang, "Vehicular wireless short-range communication for improving intersection safety," *IEEE Communications Magazine*, vol. 47, no. 11, pp. 104–110, November 2009.

[6] Allgemeiner Deutscher Automobil-Club (ADAC) Web Site. (2011, Oct. 3). Die ADAC Unfallforschung (ADAC Accident Research) [Online]. Available: http://www.adac.de/infotestrat/unfall-schaeden-und-panne/Unfallforschung

[7] F. Martinez, C.-K. Toh, J.-C. Cano, C. Calafate, and P. Manzoni, "Emergency services in future intelligent transportation systems based on vehicular communication networks," *IEEE Intelligent Transportation Systems Magazine*, vol. 2, no. 2, pp. 6–20, 2010.

[8] R. Bossom, R. Brignolo, T. Ernst, K. Evensen, A. Frötscher, W. Höfs, J. Jääskeläinen, Z. Jeftic, P. Kompfner, T. Kosch, I. Kulp, A. Kung, A.-K. Mokaddem, A. Schalk, E. Uhlemann, and C. Wewetzer, "European ITS communication architecture — Overall framework — Proof of concept implementation," EC FP7 Deliverable, *EC Information Society Technologies Programme*, Tech. Rep., March 2009.

[9] R. Grzeszczyk, J. Merkisz, P. Bogus, and T. Kaminski, "Methods and Procedures for Testing the E-Call In-Vehicle Unit for the Purpose of Its Performance Assessment and Certification," in *Proceedings of the 21st International Technical Conference on the Enhanced Safety of Vehicles (ESV)*, Stuttgart, Germany, June 2009.

[10] OnStar Web Site. (2011, Sep. 21). OnStar by GM [Online]. Available: http://www.onstar.com

[11] B&B Electronics Web Site. (2011, Sep. 9). The OBD-II Home Page [Online]. Available: http://www.obdii.com

[12] Applus+ IDIADA Web Site. (2011, Jun. 9). IDIADA: Instituto de Investigación Aplicada del Automóvil [Online]. Available: http://www.idiada.es

[13] OSGi Alliance, *OSGi Service Platform, Core Specification, Release 4, Version 4.1*. IOS Press, Inc., 2007.

[14] National Highway Traffic Safety Administration (NHTSA). (2011, May 10). 2009 Traffic Safety Facts: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System [Online]. Available: http://www-nrd.nhtsa.dot.gov/Pubs/811402.pdf

[15] M. Hall, F. Eibe, G. Holmes, B. Pfahringer, P. Reutemann, and I. H. Witten, "The WEKA Data Mining Software: An Update," *SIGKDD Explorations*, vol. 11, 2009.

[16] G. F. Cooper, and E. Herskovits, “A Bayesian method for the induction of probabilistic networks from data,” *Machine Learning*, vol. 9, pp. 309–347, 1992.

Acknowledgements

This work was partially supported by the *Ministerio de Ciencia e Innovación*, Spain, under Grant TIN2011-27543-C03-01, and by the *Diputación General de Aragón*, under Grant “subvenciones destinadas a la formación y contratación de personal investigador'”.

Manuel Fogue *earned BSc and MSc degrees from both the University of Zaragoza in 2007 and the University Jaume I of Castellon in 2009, respectively. In both cases, he graduated with honors. He is a PhD candidate in the Computer Networks research group (GRC). His research interests include VANET simulation, intelligent transportation systems, traffic safety, vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications.*

Piedad Garrido *is an assistant professor in the Department of Computers and Systems Engineering at the University of Zaragoza in Spain. She graduated in Computer Science and Documentation at the Technical University of Valencia in 1997 and 1999, respectively. She received her Ph.D. degree in Documentation from the University Carlos III of Madrid in 2008. Her current research interests include intelligent transportation systems, virtual agents, traffic safety, vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. She is member of the IEEE.*

Francisco J. Martinez *is an associate professor in the Department of Computers and Systems Engineering at the University of Zaragoza in Spain. He graduated in Computer Science and Documentation at the Technical University of Valencia in 1996 and 1999, respectively. He received his Ph.D. degree in Computer Engineering from the Technical University of Valencia in 2010. His current research interests include VANET simulation, intelligent transportation systems, traffic safety, vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. He is member of the IEEE.*

Juan-Carlos Cano *is a full professor in the Department of Computer Engineering at the Polytechnic University of Valencia (UPV) in Spain. He earned an MSc and a Ph.D. in computer science from the UPV in 1994 and 2002 respectively. From 1995-1997 he worked as a programming analyst at IBM's manufacturing division in Valencia. His current research interests include power aware routing protocols and quality of service for mobile ad hoc networks and pervasive computing.*

Carlos T. Calafate *is an associate professor in the Department of Computer Engineering at the Polytechnic University of Valencia (UPV) in Spain. He graduated with honors in Electrical and Computer Engineering at the University of Oporto (Portugal) in 2001. He received his Ph.D. degree in Computer Engineering from the Technical University of Valencia in 2006, where he has worked since 2005. He is a member of the Computer Networks research group (GRC). His research interests include mobile and pervasive computing, security and QoS on wireless networks, as well as video coding and streaming.*

Pietro Manzoni *is a full professor in the Department of Computer Engineering at the Polytechnic University of Valencia (UPV) in Spain. He received the MS degree in computer science from the "Universitá degli Studi" of Milan, Italy, in 1989, and the PhD degree in computer science from the Polytechnic University of Milan, Italy, in 1995. His research activity is related to wireless networks protocol design, modelling, and implementation. He is member of the IEEE.*