Reducing the Emergency Services Response Time using Vehicular Networks

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Abstract

This work presents e-NOTIFY, a novel proposal designed to improve the responsiveness of emergency services by reducing the time required to rescue the passengers involved in a car accident, and automatically managing and optimizing the medical and rescue resources needed. e-NOTIFY does not concentrate on reducing the number of accidents, but rather focuses on improving the rescue procedures. To this end, once the accident has occurred, e-NOTIFY tries to automatically and efficiently manage the emergency resources. Therefore, the main goal is to send SOS messages with precise information, high reliability and low delay, making it possible to predict the injury severity of occupants, and thus adapt the required rescue resources and reduce the response time of the emergency services.

1 Introduction

The number of vehicles on the road is constantly increasing, making traffic density higher and increasing the requirements for the drivers' attention. Car accidents represent a serious problem all around the world. In 2007 alone, 40,000 people were killed in Europe and more than 1.2 million were severely injured. In Spain, 2,742 people died on its roads; this means one death per 16,410 inhabitants. However, some studies conclude that a faster response of the emergency services could reduce these numbers by 11% of deaths and 12% the number of injured.

The European Commission is funding several projects under the so-called eSafety initiative [2] launched in 2002 in order to halve the number of road fatalities by 2010 [1]. This has promoted several efforts toward new safety systems among which Cooperative Systems use *vehicle-to-vehicle* (V2V) communication. These motivations are behind the i2010 Intelligent Car Initiative, one of the European Information Society Flagship initiatives adopted in February 2005.

To accomplish these objectives, communications are now considered necessary 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 data exchanged between the vehicle and the roadside infrastructure (V2I) or between vehicles (V2V).

Several years ago, passive safety systems were integrated within cars, greatly increasing traffic safety. Recently, more advanced passive safety systems combined with active safety systems allowed to reduce the number of deaths and injured in traffic accidents. Active safety has increased greatly in the last years. However, car accidents may still occur and so deeper research is necessary to improve traffic safety. In our opinion, the future of safety will be to combine active and passive safety with the currently available communication technologies, in order to develop automatic or semiautomatic driving systems.

Technology advances in wireless networking have contributed to supporting new services and applications for vehicle passenger safety and assistance. *Vehicular ad hoc networks* (VANETs) are a type of wireless network that does not require any fixed infrastructure. These networks are considered as the most adequate solution to cooperative driving among cars on the road. The integration of many sensoring capabilities on-board of vehicles, and the proposals for wireless technologies such as *Dedicated Short Range Communication* (DSRC) and IEEE 802.11p *Wireless Access for Vehicular Environment* (WAVE) enable peer-to-peer mobile communication among vehicles and are expected to provide improvements for safety.

In this paper we present e-NOTIFY, a novel proposal designed to improve the chances of survival for passengers involved in car accidents by reducing the response time of rescue teams and optimizing automatically the medical and rescue resources needed. This proposal is not concentrated on reducing the number of accidents, focusing instead on post-collision strategies to optimize the rescue procedures. Once the accident has occurred, it is crucial to efficiently manage the emergency resources. A faster and more efficient rescue increases the chances of recovery for injured people.

This paper is organized as follows: Section 2 presents the motivation of this paper. Section 3 presents our proposed architecture called e-NOTIFY. Finally, Section 4 presents some concluding remarks.

2 Motivation

Fast and efficient rescue operations following car accidents increase the probability of survival for injured occupants significantly. The so-called Golden Hour is a commonly used medical term to characterize the urgent need for the care of trauma patients. This term implies that morbidity and mortality are affected if care is not instituted within the first hour after injury.

For a sustainable reduction of time, two major steps must be addressed: (i) fast and more accurate notification of the accident to the next *Public Safety Answering Point* (PSAP), and (ii) fast and effective evacuation of occupants which are trapped inside a vehicle. Figure 1 shows the different actions to follow dur-

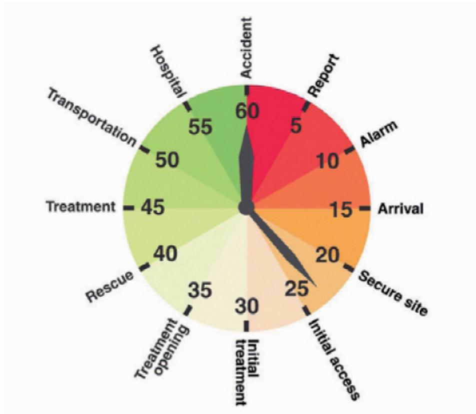

Figure 1: Golden Hour in a car accident.

ing the first precious hour after an accident.

Modern cars can be equipped with automatic accident notification systems to request medical and technical support when an accident takes place. This technology, coined eCall, has been pushed by the European Commission and could be extended to transmit relevant data about the car and the occupant to the next PSAP. For the medical staff some meaningful criteria have to be transferred as additional input of the standard eCall to the rescue center. This extra information should describe the estimated injury severity level based on sensor data of the car.

Depending on the organization of the national rescue services, reliable information for the disposition of rescue teams (including medical staff and fire brigade) is necessary. Up to now, automatic accident notification systems did not send any information relative to the condition of the occupants (e.g. injuries) or the status of the car (e.g. body status, fuel status, status of powertrain) to the rescue center or service provider. With reliable information, the right kind and amount of rescue personnel and resources could immediately be sent to the scene of the accident, leading to a reduction in both report and alarm times. Moreover, rescue operations are more difficult today due to an increasing amount of rescue interfering materials (e.g. ultra high strength steel, carbon reinforced parts, etc.). This can prolong rescue operations when different efforts have to be started by rescue crews to e.g. detach parts of the vehicle in order to extricate trapped persons.

Technical rescue personnel usually faces problems such as (i) not knowing the distribution of rescue critical materials in the vehicle's structure, and (ii) not knowing the most efficient techniques for dealing with these materials. Based on simulation and testing, new and effective rescue tools and strategies are being developed to adequately handle the demands of modern vehicles. Moreover, different cutting procedures and evacuation techniques will be examined with numerical simulation. The most efficient rescue strategies will then be made public on a web-based information platform where rescue crews can retrieve information about rescue operations either for training or accident on-site using mobile devices.

The exchange of information between communicating vehicles without any fixed infrastructure, such as access points or base stations, is an intensive field of research. Projects like FleetNet [10] propose the establishment of multi-hop ad hoc networks between vehicles based on DSRC for future vehicular communication systems. In order to participate in such a network, a vehicle has to be equipped with the necessary radio communications hardware. Since each network node acts as a wireless station and a mobile router at the same time, distant vehicles can communicate with each other by using intermediate vehicles for packet forwarding. Nowadays, information about possible ways to extricate the vehicle's occupants in certain accident situations is not provided. The used extrication technique is only based on the experience and equipment of the technical rescue staff.

The main objective of the proposed system is to define and design a prototype for an integrated infrastructure to detect and send alert messages to emergency services when road accidents occur, taking advantage of the available communication technologies such as 802.11p (VANETs) and telephony cellular networks, making it possible to build a huge database with technical rescue instructions and medical information helpful to rescue workers, thus providing an invaluable source of information for the extrication of people from accidented vehicles.

Although other technologies have been proposed in other projects, such as RFID [14], our system can bring forward the required rescue resources that must be sent to the accident, and to provide valuable information to the emergency services before them arriving to the accident zone.

3 e-NOTIFY

In this section we introduce the e-NOTIFY architecture, describing how it operates, as well as the technologies involved. The aim of e-NOTIFY is to offer an architecture that allows for (i) direct communication among the vehicles involved in the accident, (ii) automatic delivery of a data file to the Emergencies Coordination Center that contains important information about the accident, and (iii) an automatic and preliminary assessment of damages based on the received information and a database of accidents, adapting the rescue resources needed.

Figure 2 shows the proposed architecture. The aim is creating a framework that fullfills the needs of communication and infrastructure necessary to provide services to endusers in ubiquitous vehicular environments. Both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications have a special relevance. Various communication technologies are exploited, mainly VANETs and infrastructure networks, typically cellular 3G networks. We believe in the feasibility of such technologies in the area of secure transportation systems, since they make it possible to develop an integrated environment for accidented vehicles to communicate. In this regard, special attention is given to providing a common communications interface, isolating the user from handoffs or changes that may occur between the different network technologies used.

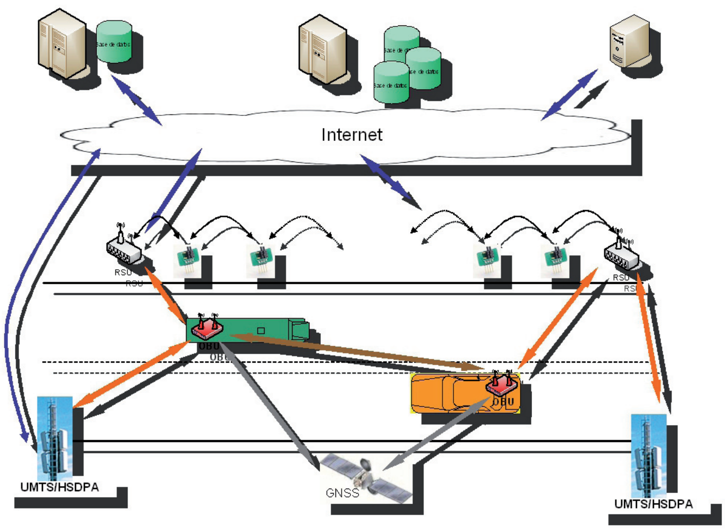

Figure 2: Scheme of the proposed architecture.

Figure 3 shows the devices required and the technologies involved in the proposed system. A core element of our system is the Internet, since it allows for communication between vehicles (at bottom), the Control Unit (right top), and the different rescue entities (left top). In our proposed system it is very important to consider and correctly define the *On-board Unit* (OBU), since it receives all the information from the sensors installed in the vehicle, and determines how and when this information should be sent to the *Control Unit* (CU) in order to warn the emergency services. This device must be technically and economically feasible. Moreover, this system must 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 shifting towards more general purpose systems due to the inclusion of new services. Hence, the OBU has to include communication interfaces to connect to the communications system.

For the initial experiments we used the ASUS WL-500g Premium wireless router [7], which contains, at a very reasonable price, all the features required to deploy the system. It includes a wireless card based on the IEEE 802.11b/g standard, and several Fast Ethernet ports to connect either to a local area network or to a wide area network. We used the two USB2.0 ports available to configure a Bluetooth connection and an HSDPA modem.

3.1 Information to Send in case of an Emergency

Rescue services currently do not have any vehicle-specific safety information available at the scene of the accident. Written rescue manuals provided by some vehicle manufacturers are impossible to manage and provide too much information to be remembered by the rescue staff in critical situations.

The electronic systems currently provide standardized information in a consistent format for all manufacturers. However, the vehicle selection should be improved so that rescue staff can select the correct vehicle model using the license plate number or *Vehicle Identification Number* (VIN) number.

In terms of the vehicle information system, current electronic information systems only of-

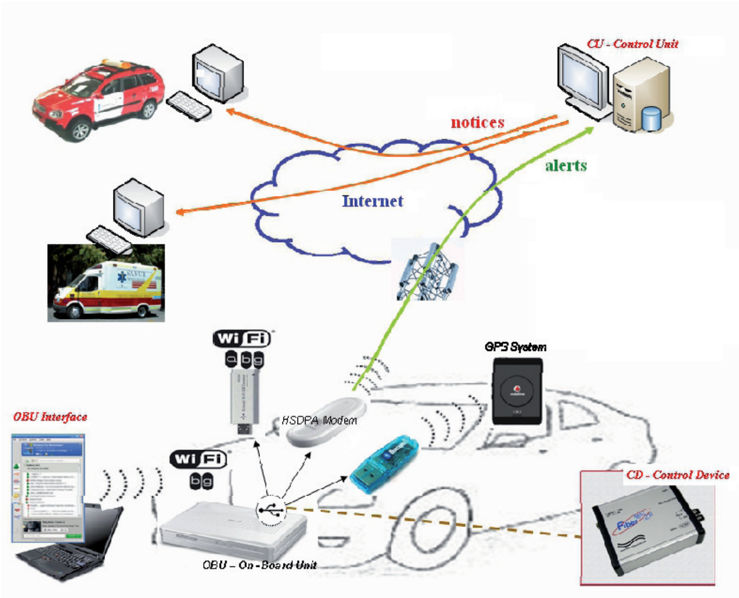

Figure 3: Devices and technologies involved in the proposed system.

fer static vehicle information related to the state of different components in the car. Automatic identification of the involved vehicles is only possible in certain countries, for instance via a licence plate request (Netherlands, Sweden) or by entering the VIN (USA). There is no connection to automatic collision notification systems, which should also be capable to select the correct vehicle information and show detailed information about the accident characteristics. The e-NOTIFY platform addresses all these issues.

With knowledge about the crash severity and the related injury severity of the occupants, the work of paramedics and/or physicians can be improved in a significant way. The first steps of a treatment can be initiated by giving information about the status of occupants. Preliminary research works have been done in the U.S. by the "William Lehman Injury Research Center" [13]. The URGENCY algorithm was developed to predict the injury risk based on observed data from the vehicle or from the paramedic. It is based on a statistical prognosis model and offers the possibility to make medical rescue (paramedic system) more efficient.

Nowadays, information about the severity of the injuries cannot be obtained. Therefore, such valuable support to the medical staff at the scene of the accident is unavailable. Furthermore, the disposition of medical staff by the rescue center after automatic notification depends primarily on information (e.g. airbag deployment) which does not correlate with the injury severity of occupants. An intelligent emergency call should contain further information focused on crash severity and injury severity. We propose to send the following set of information, which can be retrieved from the embedded vehicular sensors.

TIME

- to inform exactly when the accident occurred.

LOCATION

- **geographical position of the vehicle**, to determine the exact location of the injured.

VEHICLE-OCCUPANTS

- **characteristics of the vehicle**, to adequate the equipment to send to the accident scenario and to warn the rescue team about the level of complexity and dangers. Critical areas at the vehicle which must be avoided by cutting procedures (e.g. gas inflators) are mostly not labeled and might cause critical/dangerous situations for rescue workers. (e.g. in modern electrical engines, etc.).
- **number of passengers**, to adequate the medical team required to attend them.
- **features of the passengers**: weight, height, age, etc. The more information, the better.
- **information about seat belts and airbags**, to estimate the severity of the injured ones, how the accident occurred and the severity of the accident.

ACCIDENT

- **speed and acceleration** of the vehicle just before the accident, to estimate the severity of the accident.
- **point(s) of impact**, i.e. exactly where the impact(s) has been produced.
- **direction of impact force**. This is a mechanical concept. If we consider the top of the car as a clock, we can describe the direction of impact force as an hour. (12 for front side, 3 for right side, 6 for rear side, etc.).
- **position of the vehicle** after the crash to estimate the severity of the accident and to warn the emergency team about the level of complexity of the rescue.

Figure 4 shows the SOS Packet Format. Only 36 bytes will be sent by each accidented vehicle. All these data shall be automatically processed by the *Control Unit* (CU) to decide the resources needed to correctly control and manage the accident. The CU will compare the received data with previous data collected in a database of accidents, making it possible to predict the injury severity of occupants, and thus adapt the rescue services sent to the accident zone.

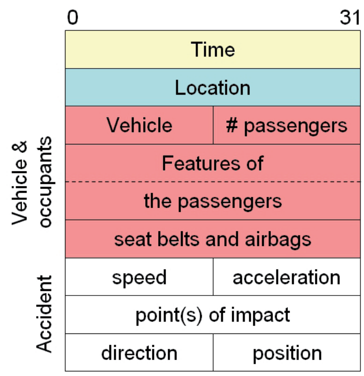

Figure 4: SOS Packet Format in the proposed system.

A number of research projects headed by research institutes and car manufacturers around the world have been focusing on inter-vehicle communication systems. Table 1 presents some of the larger projects with similar objectives as e-NOTIFY. As our proposal, they try to improve traffic safety, but with different technologies or different purposes. The most similar projects to e-NOTIFY are both the eCall project and the OnStar project, but they are less ambitious. Our proposal goes beyond their aims since we are developing an intelligent system that allows to automatically adapt the required rescue resources, allowing the rescue staff to work far more efficiently, and reducing the time associated with their tasks. Based on preliminary results obtained from our experiments, we estimate a reduction of the response time of about 20%.

4 Conclusions and Future Work

The overall goal of this work was to present a novel architecture specially designed for post-collision rescue. This architecture allows for (i) direct communication among the vehicles involved in the accident, (ii) automatic deliv-

Table 1: Related Projects in the Road Transport Safety Area

Projects	**Remarks**
Fleetnet [8] / Network on Wheels [5]	This project was set up by a German consortium and was funded between 2000 and 2003. The main objective of the project was to develop a platform for IVC systems focused on three classes of applications: cooperative driving, traffic information, and comfort applications. Currently, this consortium is working on a new project named Network on Wheels. Its main objectives are to solve questions on the communication protocols and data security for the targeted vehicular communications.
CarTalk 2000 [11]	It was funded between 2001 and 2004 by the EU within the 5th Framework Program. Its main objectives were the development of cooperative driver assistance systems and a self-organizing ad hoc radio network as the basis for communication with the aim of preparing a future standard. It incorporated three applications: a warning system that relays information about accidents ahead, break-downs and congestion; a longitudinal control system; and a cooperative driving assistance system that supports merging and weaving.
SafeSpot [9]	An integrated research project co-funded by the European Commission Information Society Technologies among the initiatives of the 6th Framework Program. The objective of the project is to understand how intelligent vehicles and intelligent roads can cooperate to increase road safety.
eCall [4]	It is designed to improve transportation safety by providing rapid assistance to motorists involved in a collision anywhere in the European Union. A collision activates on-vehicle sensors causing an emergency voice call (E112) to be established via the cellular network to local emergency agencies. In addition to enabling two-way speech communication between the driver and the PSAP, e-Call employs an in-band voice-channel modem to transmit a *Minimum Set of Data* (MSD) including key information about the accident such as time, location and vehicle description, which are sent to the PSAP operator receiving the voice call.
PReVENT [12]	This is another project funded by the European Union. One of the objectives of this project is to contribute to the congregation and cooperation of European and national organizations and their road transport safety initiatives.
COMeSafety [3]	A project that is focused on all issues related to vehicle-to-vehicle and vehicle-to-infrastructure communications as the basis for cooperative intelligent road transport systems.
URGENCY [13]	A project developed to predict the injury risk based on observed data from the vehicle or from the paramedic. It is based on a statistical prognosis model and offers the possibility to make medical rescue more efficient.
OnStar [6]	In-vehicle safety and security system created by General Motors (GM) for on-road assistance that is very similar to the European eCall project. A collision activates on-vehicle sensors, causing an emergency voice call, and sending key information about the accident. Unlike eCall, OnStar provides an on-road navigation system and assistance in case the vehicle is stolen; it can also remotely unlock vehicles.

ery of a data file to the Control Unit that contains important information about the accident, and (iii) an automatic and preliminary assessment of damages based on the received information and a database of accidents, adapting the rescue resources needed.

Once the system has been defined, future work includes the development of a prototype to be installed in vehicles. This development will be carried out by the engineers of Passive Safety, Active Safety and Electronics departments of Applus+Idiada with the collaboration of the GRC research group from the Universidad Politécnica de Valencia. We will elaborate a detailed report on the legal framework in terms of security and privacy in wireless communications. Afterwards, we will define how to incorporate the sensors to the vehicle. Finally, we will implement all the services offered by the system and the OBU itself, and then perform all the necessary tests to validate the system.

Acknowledgments

We would like to thank Applus+IDIADA Automotive Tech. for allowing us to test the system in its facilities and for collaborating with the setting up of the experiments. This work was partially supported by the *Ministerio de Educación y Ciencia*, Spain, under Grant TIN2008-06441-C02-01 and by the *Fundación Antonio Gargallo*, under Grant 2009/B001.

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