Emergency Services in Future Intelligent Transportation Systems Based on Vehicular Communication Networks

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***Abstract*—**Over the years, we have harnessed the power of computing to improve the speed of operations and increase in productivity. Also, we have witnessed the merging of computing and telecommunications. This excellent combination of two important fields has propelled our capability even further, allowing us to communicate anytime and anywhere, improving our work flow and increasing our quality of life tremendously. The next wave of evolution we foresee is the convergence of telecommunication, computing, wireless, and transportation technologies. Once this happens, our roads and highways will be both our communications and transportation platforms, which will completely revolutionize when and how we access services and entertainment, how we communicate, commute, navigate, etc., in the coming future. This paper presents an overview of the current state-of-the-art, discusses current projects, their goals, and finally highlights how emergency services and road safety will evolve with the blending of vehicular communication networks with road transportation.

***Index Terms*—**Vehicular ad hoc networks, road safety, emergency services, inter-vehicular communication.

I. Introduction

The population of the world has been increasing, with China and India being the two most densely populated countries. Road traffic has also been getting more and more congested, as a higher population and increased business activities result in greater demand for cars and vehicles for transportation. While careful city planning can help to alleviate transportation problems, such planning usually does not scale well over time with unexpected growth in population and road usage.

Modernization, migration, and globalization have also taken great tolls on road usage. Inadequacy in transportation infrastructures can cripple a nation's progress, social well-being, and economy. It can also make a country less appealing to foreign investors and can cause more pollution as vehicles spend a longer time waiting on congested roads. Increased delays can also result in road rage, which gives rise to more social problems, which are undesirable. With fuel price soaring and potential threats of fuel shortage, we are now faced with greater challenges in the field of transportation systems. In addition to this trend, technology has also impacted transportation, giving it a different outlook.

Previously, we were focused on how to build efficient highways and roads. Over time, the focus shifted to mechanical and automotive engineering, in the pursuit of building faster cars to surmount greater distances. Later on, electronics technology impacted the construction of cars, embedding them with sensors and advanced electronics, making cars more intelligent, sensitive and safe to drive on. Now, innovations made so far in wireless mobile communications and networking technologies are starting to impact cars, roads, and highways. This impact will drastically change the way we view transportation systems of the next generation and the way we drive in the future. It will create major economic, social, and global impact through the transformation over the next period of 10–15 years. Hence, technologies in the various fields have now found common grounds in the broad spectrum of Next Generation *Intelligent Transportation Systems* (ITS). In this paper, we examine the impact of future ITS technologies on road safety and emergency services.

II. Current State & World Trends

There have been several projects and research efforts conducted globally to address road safety, vehicular communication networks, and telematics. IN KOREA—The Korean Telematics Business Association was established in 2003 with the aim of boosting the telematics industry and to standardize telematic technologies and services. Its members are primarily automakers, telecommunication companies, terminal manufacturers, and content providers. Its core functions include: (a) coordinating Korean government projects related to telematics, (b) market promotion, (c) standardization efforts, and (d) international collaboration in conferences, road shows, etc.

IN JAPAN—The topics on ITS have been actively worked on by Japanese researchers and Japanese government agencies over the years. Specifically, the *Japanese Ministry of Land, Infrastructure and Transport* (MLIT) is the bureau in the Japanese government that decides on policies in ITS. In Japan, ITS are viewed as a new transport system comprised of an advanced information and telecommunications network for users, roads, and vehicles. Specifically, nine developments areas have been identified: (a) navigation systems, (b) electronic toll collection (ETC) systems, (c) assistance for safe driving, (d) optimization of traffic

Table 1. ITS Projects in Japan.

Japan ITS Funded Projects	Remarks
AHS [1]	Advanced Cruise-Assistance Highway Systems It aims to reduce traffic accidents, enhance safety, improve transportation efficiency, as well as reduce the operational work of drivers. AHS research is being carried out in the following fields: • AHS-"i" (information): focusing on providing information. • AHS-"c" (control): vehicle control assistance. • AHS-"a" (automated cruise): fully automated driving. Its applications include obstacle detection and avoidance, speed control, driving control and man-machine interface.
ASV [1]	Advanced Safety Vehicle It was launched in order to transfer advanced technologies to vehicles for their greater safety. In the second phase, the extent of research has been expanded to include trucks, buses and motorcycles. Automated driving technology and vehicle basic technology areas have been added to the major safety technology field. Also, research and development will be promoted in connection with infrastructures, using two systems: autonomous type and infrastructure-employed type. This will make it possible to combine ASV with AHS.

management, (e) efficiency in road management, (f) support for public transport, (g) efficiency in commercial vehicles, (h) support for pedestrians, and (i) support for emergency vehicle operations. Table 1 shows the most important ITS projects funded by the Japanese MLIT. Both projects aim to enhance safety, reduce traffic accidents while improving transportation efficiency.

IN THE USA—There are two major programs sponsored by the US *DoT* (Department of Transportation). The first one is the *Vehicle Safety Communication* (VSC) project. The second one is related to *Vehicle Infrastructure Integration* (VII). A VII consortium has been formed to engage key industrial players, state and local governments and other partners to work on an information infrastructure for real-time communications among vehicles. The motivations for a VII program in the USA are well justified. American roadways indeed have a safety and congestion problem. Accordingly, in 2006, there were 6 million traffic crashes in the USA alone, injuring about 2.6 million people. Also, it was observed that a crash occurred every 5 seconds, with someone sustaining a traffic-related injury every 12 seconds. Worse, someone died in a traffic crash every 12 minutes. This death toll is major and astonishing. In addition, road congestion problems have resulted in 4.2 billion hours of travel delay, 2.9 billion gallons of gasoline fuel wasted, and a net urban congestion cost of about $80 billion (according to a 2007 report by the Texas Transportation Institute). Table 2 shows the most important USA ITS projects.

IN EUROPE—There are a lot of integrated projects funded by the European Commission under the EU IST 6th Framework (FP6) (2002–2006), and the EU 7th Framework (FP7) extends the program further till 2013. The White Paper on EU Transport Policy for 2010 states a key objective, i.e., 50% reduction of casualties due to road accidents by the end of 2010. Improvements on road safety are achievable by increasing the EU market penetration of *Advanced Driver Assistance Systems* (ADAS), currently limited by performance and cost of sensor technologies. This is the

Table 2. ITS Projects in the USA.

USA ITS Funded Projects	Remarks
VSC [2]	Vehicle Safety Communication The main objectives of the VSC project are: • Estimate potential safety benefits for potential vehicle safety applications. Define preliminary communications requirements for the high-priority vehicle safety applications. • Evaluate proposed DSRC standards, identify specific technical issues, present vehicle safety requirements, and secure necessary revisions in eight major areas. Confirm the viability of DSRC for safety applications at real intersections. • Identify channel capacity in stressing traffic environments as a large scale deployment issue, determining that the 5.9 GHz DSRC wireless technology is potentially best able to support the communications requirements.
VII [3]	Vehicle Infrastructure Integration VII will enable safety, mobility, and commercial vehicular services and applications. It will exploit innovations in wireless communications and networking technologies, along with sensing and advanced user interfaces. When deployed, the VII network will allow drivers and travelers to access traffic conditions and routing information, receive warnings about existing or upcoming hazards, and conduct wireless commercial transactions while on-the-move.

Table 3. ITS Projects in EU.

EU ITS Funded Projects	Remarks
AIDE [4]	Adaptive Integrated Driver-vehicle Interface The general objective is to generate knowledge and develop methodologies and human-machine interface technologies required for safe and efficient integration of ADAS (Advanced Driver Assist Systems), IVIS (In-Vehicle Information Systems) and nomad devices into the driving environment. The aims of AIDE are: • to maximize the efficiency, and hence the safety benefits, of advanced driver assistance systems • to minimize the level of workload and distraction imposed by in-vehicle information systems and nomad devices • to enable the potential benefits of new in-vehicle technologies and nomad devices in terms of mobility and comfort.
AIDER [5]	Accident Information and Driver Emergency Rescue The AIDER project's main objective is the reduction of road accident consequences by optimizing the rescue management in terms of operative time and effectiveness. AIDER vehicles will be equipped with a detection system to monitor the on-board pre- and post-crash environment. The project envisaged a kind of automotive 'black box', which would continually assess a car's environment, including speed, terrain and many other factors. Should there be an accident, the box would perform a quick calculation, comparing the state of the vehicle before and after impact. This would yield important information about where the car was hit, how quickly the car stopped, and therefore how severe the accident was. The box would then alert a call center with essential details about the nature of the crash, which could be reconstructed. Since the emergency services would be contacted immediately and provided with details about the accident, they would arrive more quickly and be better prepared for specific injuries.
ATLANTIC [6]	A Thematic Long-term Approach to Networking for the Telematics & ITS Community The ATLANTIC Thematic network will operate as an Electronic Forum organized and coordinated through three geographically based network coordinators, one for each of Europe, Canada and USA. The ATLANTIC project has three parts: (1) Operation of an ITS Forum based on e-mail groups, involving key individuals involved in Transport Telematics and Intelligent Transport Systems (ITS). The Forum sub-groups will be benchmarking the coverage, content and results from the European ITS programs against similar activities in the USA and Canada. (2) International meetings with American and Canadian partners in the project, who are self-funded. (3) Development of good practice and policy on telematics based travel information services for cities and regions.
PREVENT [7]	Preventive and Active Safety Applications Contribute to the Road Safety Goals on European Roads In PReVENT, a number of subprojects are proposed within the clearly complementary function fields: Safe Speed and Safe Following, Lateral Support and Driver Monitoring, Intersection Safety, and Vulnerable Road Users and Collision Mitigation. The goal of Integrated Project PReVENT is to contribute to the: • Road safety goal of 50% fewer accidents by 2010–as specified in the key action eSafety for Road and Air Transport from the European Union. • Competitiveness of the European automotive industry. • European scientific knowledge community on road transport safety. • Congregation and cooperation of European and national organizations and their road transport safety initiatives.
ADOSE [8]	Reliable Application Specific Detection of Road Users with Vehicle On-board Sensors ADOSE addresses research challenges in the area of "accident prevention through improved-sensing including sensor fusion and sensor networks". Focus is also on "increased performance, reliable and secure operation" for "new generation advanced driver assistance systems". The project is focused mainly on sensing elements and their pre-processing hardware, as a complementary project to PReVENT. Novel concepts and sensory systems will be developed based on Far Infrared cameras, CMOS vision sensors, 3D packaging technologies, ranging techniques, bio-inspired silicon retina sensors, harmonic microwave radar and tags.
INTERSAFE-2 [9]	Cooperative Intersection Safety The INTERSAFE-2 project aims to develop and demonstrate a Cooperative Intersection Safety System (CISS) that is able to significantly reduce injury and fatal accidents at intersections. The novel CISS combines warning and intervention functions based on novel cooperative scenario interpretation and risk assessment algorithms. The cooperative sensor data fusion is based on advanced on-board sensors for object recognition, a standard navigation map, and information supplied over a communications link from other road users via V2V and infrastructure sensors and traffic lights via V2I.
SAFERIDER [10]	Advanced Telematics for Enhancing the Safety and Comfort of Motorcycle Riders SAFERIDER aims to study the potential of ADAS/IVIS integration on motorcycles for the most crucial functionalities, and develop efficient and rider-friendly interfaces and interaction elements for riders' comfort and safety. SAFERIDER aims to enhance riders' safety by introducing four ADAS applications: (a) speed alert, (b) curve speed warning, (c) frontal collision warning, and (d) intersection support.
COOPERS [11]	Cooperative Networks for Intelligent Road Safety COOPERS focuses on the development of innovative telematic applications on the road infrastructure with the long term goal of a Cooperative Traffic Management between vehicle and infrastructure, thus reducing the self opening gap on telematic application development between car industry and infrastructure operators. The goal of the project is the enhancement of road safety by direct and up-to-date traffic information based on wireless communication between infrastructure and motorized vehicles on a motorway section.
HIGHWAY [12]	Breakthrough Intelligent Maps and Geographic Tools for the context-aware-delivery of E-safety and added value services HIGHWAY combines smart real-time maps, UMTS 3G mobile technology, positioning systems and intelligent agent technology, 2D/3D spatial tools, and speech synthesis/voice recognition interfaces to provide European car drivers and pedestrians with eSafety services and interaction with multimedia (text, audio, images, real-time video, voice/graphics) and value-added-location-based services. HIGHWAY maps will help drivers facing critical driving situations.

Table 3. ITS Projects in EU (Cont.)

EU ITS Funded Projects	Remarks
I-WAY [13]	Intelligent Cooperative Systems in Car for Road Safety The goal of I-WAY is to develop a multi-sensorial system that can ubiquitously monitor and recognize the psychological condition of driver as well as special conditions prevailing in the road environment. The I-WAY platform targets mainly road users, but it is a highly modular system that can be easily adapted or break up in standalone modules in order to accommodate a wide variety of applications and services in several fields of transport, thanks to its interoperability and scalable system architecture. The I-Way project is strongly committed to achieve the two strategic objectives of (a) increasing road safety, and (b) bettering transport efficiency.
COMeSafety [14]	Communications for eSafety The COMeSafety Project supports the eSafety Forum with respect to all issues related to V2V and V2I communications as the basis for cooperative intelligent road transport systems. COMeSafety provides an open integrating platform, aiming for the interests of all public and private stakeholders to be represented. COMeSafety acts as a broker for the consolidation and following standardization of research project results, work of the C2C-CC and the eSafety Forum. Its aims are: • Co-ordination and consolidation of research results and their implementation. • eSafety Forum support in case of Standardization and Frequency Allocation. • Worldwide harmonization (Japan/US/Europe). • Support the frequency allocation process. • Dissemination of the results.
CarTALK2000 [15]	Advanced driver support system based on V2V communication technologies CarTALK2000 was established within the EU's ADASE2 (Advanced Driver Assistance Systems Europe) ITS project. 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 [16]	Cooperative vehicles and road infrastructure for road safety The objective of the project is to understand how intelligent vehicles and intelligent roads can cooperate to increase road safety. SAFESPOT seeks to: • Use the infrastructure and the vehicles as sources and destinations of safety-related information and develop an open, flexible and modular architecture and communications platform. • Develop the key enabling technologies: ad-hoc dynamic network, accurate relative localization, dynamic local traffic maps. • Develop and test scenario-based applications to evaluate the impacts on road safety. • Define a sustainable deployment strategy for cooperative systems for road safety, evaluating also related liability, regulations and standardization aspects.
CVIS [17]	Cooperative Vehicle-Infrastructure Systems Contrarily to SafeSpot, this European project focuses on vehicle-to-infrastructure communications alone. The goals set are: • To create a unified technical solution allowing all vehicles and infrastructure elements to communicate with each other in a continuous and transparent way using a variety of media with enhanced localization. • To define and validate an open architecture and system concept for a number of cooperative system applications, and develop common core components to support cooperation models in real-life applications and services for drivers, operators, industry and other key stakeholders. • To address issues such as user acceptance, data privacy and security, system openness and interoperability, risk and liability, public policy needs, cost/benefit and business models, and roll-out plans for implementation.

prime focus of European ITS research program. Table 3 describes some of the most relevant ITS projects funded by the European Union. These projects cover a wide spectrum, including driver-vehicle interface, emergency rescue, preventive road safety, on-board sensors, pedestrian detection, intersection safety, cooperative systems and cooperative networks, maps and geographical technologies, and *vehicle-to-vehicle* (V2V) communications. In this paper, we focus on how vehicular communication networks have impacted road safety and how emergency services will evolve in the future.

III. Vehicular Networks: Rationale & Motivation

In the past, the automotive industry built powerful and safer cars by embedding advanced materials and sensors. With the advent of wireless communication technologies, cars are being equipped with wireless communication devices, enabling them to communicate with other cars. Such communications are not plainly restricted to data transfers (such as emails, etc.), but also create new opportunities for enhancing road safety. Some applications only require communication among vehicles, while other applications require the coordination between vehicles and road-side infrastructure.

Table 4. ITS/VANET testbeds developed by National Labs and Universities.

Institution	Remarks
Carnegie Mellon University [20]	The GM Collaborative Research Lab at Carnegie Mellon University developed the Smart Car testbed which allows the car to recognize the driver's settings and keep him alert. It has the following features: • "Context aware", i.e. it responds to driver's needs and preferences, road and weather conditions, and information from the Internet based on demand. • It is also equipped with a "gesture interface" that allows drivers to control the car's electronics with a wave of their hand. • Built with a speech recognition system tuned to the driver's voice that connects the car to handheld computers and cell phones. • Assembled with a heads-up display for operating the radio, navigating, checking email, and the driver's schedule.
German Consortium [21]	A Consortium formed by automotive and telecommunication companies, the state government, and German universities is collaborating in the simTD initiative which tries to put the results of previous research projects into practice. The overall simTD test fleet comprises an internal fleet with up to 100 controlled test vehicles as well as an external fleet with approximately 300 vehicles. The internal simTD fleet of test vehicles comprises 20 core vehicles with expert drivers. 80 further vehicles are driven by persons without special training. The expert drivers will be asked to work together locally and on their own initiative to create certain scenarios. The other drivers' reaction to the respective scenario can then be used to evaluate its efficiency, safety, and acceptability of functions.
Rutgers University [22]	The DisCo Lab developed TrafficView which defines a framework to disseminate and gather information about the vehicles on the road. With such a system, vehicle's driver will be provided with road traffic information that helps driving in situations such as foggy weather, or finding an optimal route in a trip several miles long. The demonstration of the TrafficView system was performed with four vehicles, which continuously exchanged speed and location information over wireless networking technology, as they navigated across the Rutgers University campus.
Berkeley [23]	The California Partners for Advanced Transit and Highways (PATH) and the Department of Transportation (Caltrans) in partnership with public agencies and private industry are working in vehicle-to vehicle and vehicle-to-roadside communications on their IntelliDrive (formerly Vehicle-Infrastructure Integration, VII) testbed. IntelliDrive is a multimodal initiative that aims to enable safe, interoperable networked wireless communications among vehicles, the infrastructure, and passengers' personal communications devices.

The applications and advantages of using vehicular communication networks for enhancing road safety and driving efficiency are diverse, which explains emerging research in this area lately. Vehicular communications, however, need the support of reliable link and channel access protocols. The IEEE 802.11p *wireless access in vehicular environments* (WAVE) is a standardization effort that provides a protocol suite solution to support vehicular communications in the licensed frequency band at 5.9 GHz (5.85–5.925 GHz). A WAVE system consists of: (a) *Roadside units* (RSUs), and (b) *Onboard units* (OBUs) which are mounted in vehicles. By default, WAVE units operate independently, exchanging information over a fixed radio channel known as the *control channel* (CCH). However, they also can organize themselves in small networks called *WAVE basic service sets* (WBSSs), which are similar in nature to the service sets defined in IEEE 802.11. Therefore, WAVE supports both *vehicle-to-infrastructure* (V2I) and *vehicle-to-vehicle* (V2V) communications. WAVE can enhance road safety and driving efficiency since it offers the required support to provide faster rescue operations, perform localized warning of potential danger, and convey real-time accident warnings. WAVE complements satellite, WiMax, 3G, and other communications protocols by providing high data transfer rates (3–54 Mbps) in circumstances where the latency in the communication link is too high and isolating relatively small communication zones is important. Details about radio frequencies, modulation, link control protocols and media access can be found in [18].

Concerning safety using vehicular networks, in [19], cars can act as communication relays (routers) to form ad hoc vehicular networks via wireless communication links. Cars are restricted by the physical boundaries of the road and highways. For example, cars on one lane all travel in the same direction, keeping ample safe distance from one another. The ability of neighboring cars to communicate wirelessly allows them to warn each other about any abnormalities or potential dangers. This, in contrast to the old way of "signaling" using visual lights, is far superior, especially when visibility is poor due to bad weather conditions. Another scenario is the ability of cars to convey accident information to other neighboring cars via V2V communications so that they can slow down and be aware of the potential danger ahead. Also, in times of road congestion, V2V communications can allow other cars further down the road to make plans to exit the highway or to seek alternate routes to their destinations, hence avoiding further congestions. Table 4 shows some of the major testbeds related to ITS/VANET developed by National Labs and Universities that have been used to test and evaluate vehicular network solutions.

V2V communications have the following advantages: (i) allow short and medium range communications, (ii) present lower cost of deployment, (iii) support short messages delivery, and (iv) minimize latency in the communication

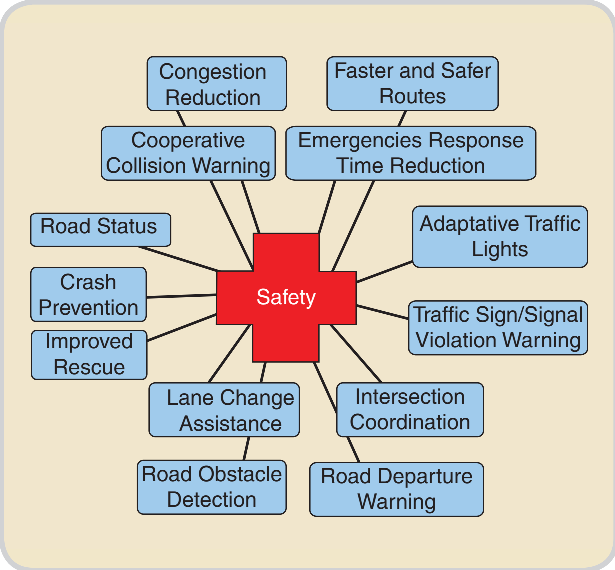

FIG 1 The many aspects of road safety.

link. Nevertheless, V2V communications present the following shortcomings: (i) frequent topology partitioning due to high mobility, (ii) problems in long range communications, (iii) problems using traditional routing protocols, and (iv) broadcast storm problem in high dense scenarios. Currently, there are several existing projects that address V2V communication issues. Wisitpongphan et al. in [24] quantified the impact of broadcast storms in VANETs in terms of message delay and packet loss rate in addition to conventional metrics such as message reachability and overhead. They proposed three probabilistic and timer-based broadcast suppression techniques: (i) the weighted p-persistence, (ii) the slotted 1-persistence, and (iii) the slotted p-persistence scheme. The authors also studied the routing problem in sparse VANETs [25]. In [26], they proposed a new Distributed Vehicular Broadcasting protocol (DV-CAST) to support safety and transport efficiency applications in VANET. Results showed that broadcasting in VANET is very different from routing in mobile ad hoc networks (MANET) due to several reasons such as network topology, mobility patterns, demographics, traffic patterns at different times of the day, etc. These differences imply that conventional ad hoc routing protocols will not be appropriate in VANETs for most vehicular broadcast applications. The designed protocol addressed how to deal with extreme situations such as dense traffic conditions during rush hours, sparse traffic during certain hours of the day (e.g., midnight to 4 am in the morning), and low market penetration rate of cars using DSRC technology.

Concerning V2I, current research efforts include: (a) information dissemination for VANETs, especially using advanced antennas [27], (b) VANET/Cellular interoperability [28], and (c) WiMAX [29]. The integration of *Worldwide Interoperability for Microwave Access* (WiMAX) and Wireless fidelity (WiFi) technologies seems to be a feasible option for better and cheaper wireless coverage extension in vehicular networks. WiFi, under the 802.11p standard, is a good candidate to be used in V2V communications. Its weakness is short coverage. WiMAX multi-hop relay networks that employ relay stations could extend coverage and reduce the cost of deploying a vehicular infrastructure in the near future. With the emergence of new applications (Internet access, infotainment, social networking, etc.), the use of fixed infrastructure will become an attractive option [24].

A prerequisite for the successful deployment of vehicular communications is to make the system secure. It is essential, for example, to make sure that critical information cannot be modified by any attacker (hacker). Recently, there has been some work dealing with security for VANETs. In [30], the authors provided a detailed threat analysis and devised an appropriate security architecture. They also provided a set of security protocols, and analyzed their robustness. In [31], the authors showed how to achieve efficient and robust pseudonym-based authentication. They presented mechanisms that reduce the security overhead for safety beaconing, and retain robustness for transportation safety, even in adverse network settings. Their proposal enabled vehicle on-board units to generate their own pseudonyms, without affecting the system security. In [32], the authors suggested a method of using on-board radar to detect neighboring vehicles and to confirm their announced coordinates. They addressed position security and ways to counteract Sybil attacks.

IV. Road Safety & Emergency Services

As shown in Figure 1, safety for drivers and commuters involves several factors. It includes understanding the road conditions, having an appropriate response time towards emergencies, crash prevention procedures, etc. Overall, it is accepted that increased road safety can be achieved by exchanging relevant safety information via V2V and V2I communications, where alert information is either presented to the driver or used to trigger active safety systems (such as airbags and emergency brakes). Some of these applications will only be possible if the penetration rate of VANET-enabled cars is high enough.

A collision warning system on a vehicle needs to know the trajectories of neighboring vehicles and the configuration of the neighboring roadway. Most collision warning systems in the literature learn the state of the neighborhood by using sensors like radar or laser vision systems. In contrast, modern *Cooperative Collision Warning* (CCW) systems will construct their knowledge of the neighborhood by listening to the wireless transmissions of other vehicles. This has the advantage of a potentially inexpensive complement of on-board vehicle equipment (compared to ranging sensors, that could provide 360-degree coverage), as well as providing information from vehicles that may be occluded from direct line of sight to the approaching vehicle [33]. Examples of CCW applications are: (a) *Forward Collision Warning* (FCW), where a host vehicle uses messages from the immediate forward vehicle in the same lane to avoid forward collisions, (b) *Lane Change Assistance* (LCA), where a host vehicle uses messages from the adjacent vehicle in a neighboring lane to assess unsafe lane changes, and (c) *Electronic Emergency Brake Light* (EEBL), where a host vehicle uses messages to determine if one, or more, leading vehicles in the same lane are braking.

Cooperative Driving allows drivers to share information about traffic in order to reduce the incidence of traffic jams, minimize CO2 emissions and prevent accidents on the road. It could also help authorities by providing information about vehicles, their location, and road conditions.

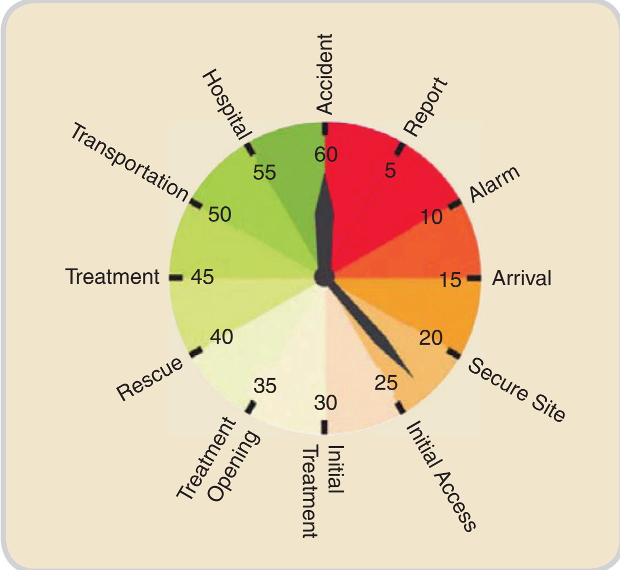

FIG 2 Golden hour in a car accident.

A. Hazards/Accident Contributing Factors

Road hazards can involve drivers, passengers, and pedestrians on the road. On residential roads, pedestrians are vulnerable as they walk along the sides of the road. At intersections, drivers, passengers, and pedestrians are vulnerable to accidents and collisions. At sharp blends and angles, cars can lose sight of other cars coming from the opposite lane, resulting in unexpected front-end collisions. Poor environmental conditions such as bad weather can also cause accidents. Under situations of heavy rain and fog, poor visibility is the prime factor contributing to car accidents. Slippery roads can also cause cars to skid and result in accidents. Other factors such as natural disasters (e.g. earthquakes) can also result in accidents. Notice that not all environment-based accidents can be rectified or improved.

Another cause for accidents is the driver himself. Drivers who are criminals on-the-run frequently drive at high speeds to avoid police chase. They ignore other on-going vehicles and, at times, even drive in the opposite lane. Such accidents are usually catastrophic. Reckless drivers are those who are usually careless. They change lane without signaling or observing the presence of neighboring cars, resulting in accidents. Fatigued drivers are those who have exhausted themselves physically and hence become less alert while driving. They, too, contribute to accidents due to their slow response to changing road conditions.

The golden hour after a car crash is illustrated by Figure 2. It is the time within which medical or surgical intervention by a specialized trauma team has the greatest chance of saving lives. If more than 60 minutes have elapsed by the time the patient reaches the operating table, the chances of survival fall sharply. As shown, typical arrival of medical help takes about 15 minutes. Initial access and treatment only start 25 minutes later. Transportation of the injured to the hospital only takes place 50 minutes later. Hence, time is critical to the survival of the injured in a severe incident. Often, hurdles get in the way of doctors and paramedics, dramatically slowing down the time it takes to get to a patient. Hence, any technologies capable of improving the golden hour will help to save lives.

When an accident occurs, crash detection systems can increase the protection of vehicle occupants by detecting and recognizing the type and severity of the crash, adapting protection systems to the body features and seating positions of passengers depending on the type and seriousness of the impact. Deployment of protective devices must be made in less than 5 milliseconds. Collision impact can be: (a) front impact – where front airbags are deployed and seat-belt tensioners are triggered as early as possible in co-ordination with the airbag concerned, (b) side impact – where thorax and head bags are deployed, (c) rear impact – where seat-belt tensioners are triggered even at low speeds to prevent whiplash injuries, and (d) rollover – where the rollover bar, seat-belt tensioners, and side and head airbags are triggered.

Generally, *crash detection systems* (CDS) can be divided into pre-crash and post-crash systems. A pre-crash system is a passive automobile safety system designed to reduce the damage caused by a collision. Most CDS use radar, and sometimes laser sensors or cameras to detect an imminent crash. Depending on the system, they may warn the driver, pre-charge the brakes, retract the seat belts (removing excess slack) and automatically apply partial or full braking to minimize the crash. Other experimental systems allow the vehicle to strengthen its frame just before a side-on collision [34], or to stop automatically before an impact [35]. Table 5 shows some pre-crash systems developed by car manufacturers.

Table 5. Pre-crash developed systems by Car Automakers.

Brand	Remarks
Audi	Audi has developed a system called "Pre-Sense Plus", which works in four phases. In the first phase, the system provides warning of impending accident, while the hazard warning lights are activated, the side windows and sunroof are closed and the front seat belts are tensioned. In the second phase, the warning is followed by light braking but strong enough to win the driver's attention. The third phase initiates autonomous partial braking at a rate of 3 m/s2. The fourth phase decelerates the car at 5 m/s2 followed by automatic deceleration at full braking power, roughly half a second before the projected impact. A second system called "Pre-Sense Rear" is designed to reduce the consequences of rear end collisions. Sunroof and windows are closed, seat belts are tightened in preparation for impact. The system uses radar technology and will be introduced on the 2011 Audi A8.
Ford	Collision Warning with Brake Support was introduced in 2009 on the Lincoln MKS and MKT and the Ford Taurus. This system provides a warning through a Head Up Display (HUD) that visually resembles brake lamps. If the driver does not react, the system pre-charges the brakes and increases the brake assist sensitivity to maximize driver braking performance.
GM	At the end of 2005, GM announced a collision warning system which was based on vehicle-to-vehicle wireless communications. Speeds, direction, and location, enabled the system to evaluate the level of warnings according to the data it had collected. The system is called "Sixth Sense", and it provides the information at hand and can give the driver a clear warning of another vehicle on the freeway that is either slowing down ahead or pulling across from the side. The system uses a clever mix of GPS receivers and LAN networks and establishes communication with other vehicles within a few hundred meters.
Honda	• Collision Mitigation Brake System introduced in 2003 on the Inspire uses a radar-based system to monitor the situation ahead and provide automatic braking if the driver does not react to a warning in the instrument panel and a tightening of the seat belts. This was the first system to provide automatic braking. • In late-2004 Honda developed an Intelligent Night Vision System which highlights pedestrians in front of the vehicle by alerting the driver with an audible chime and visually displaying them via a HUD.
Mercedes-Benz	• Pre-Safe system was unveiled in the fall of 2002 at the Paris Motor Show. Using Electronic Stability Programme (ESP) sensors to measure steering angle, vehicle yaw and lateral acceleration, and Brake Assist sensors to detect emergency braking, Pre-Safe can tighten seat belts, adjust seat positions and close the sunroof if it detects possible collision (including rollover). • Pre-Safe Brake introduced in the fall of 2005 co-operating with simultaneously introduced Brake Assist Plus and Distronic Plus systems provide all the functions of previous Pre-Safe system while adding a radar-based system which monitors the traffic situation ahead and provides automatic partial braking (40% or up to 0.4g deceleration) if the driver does not react to the Brake Assist Plus warnings. • In 2009, Mercedes unveiled Attention Assist which, based on 70 parameters, attempts to detect the driver's level of drowsiness based on the driver's driving style. This system does not actually monitor the driver's eyes. • Also in 2009 Mercedes added a fully autonomous braking feature that will provide maximum braking at approximately 0.6 seconds before impact.
Nissan	Nissan is reportedly developing a new "magic bumper" system which raises the accelerator pedal if it senses an impending collision. Once the driver lifts off the pedal, the system then automatically applies the brakes. Infiniti offers a laser-based system for the US market that pre-pressurizes the braking system so maximum force can be applied early.
Toyota	• Pre-Collision System is the very first radar-based pre-crash system which uses a forward facing millimeter-wave radar system. When the system determines a frontal collision is unavoidable, it preemptively tightens the seat belts removing any slack and pre-charges the brakes. Advanced Pre-Collision System added a twin-lens stereo camera located on the windshield and a more sensitive radar to detect for the first time smaller "soft" objects such as animals and pedestrians. A near-infrared projector located in the headlights allows the system to work at night. • In 2007, the world's first Driver Monitoring System was introduced on the Lexus LS, using a CCD camera on the steering column; this system monitors the driver's face to determine where the driver is looking. If the driver's head turns away from road and a frontal obstacle is detected, the system will alert the driver using a buzzer and if necessary pre-charge the brakes and tighten the safety belts. • In 2008, the Toyota Crown monitors the driver's eyes to detect the driver's level of wakefulness. This system is designed to work even if the driver is wearing sunglasses. Toyota added a pedestrian detection feature which highlights pedestrians and presents them on an LCD display located in front of the driver. The latest Crown also uses a GPS-navigation linked brake assist function. The system is designed to determine if the driver is late in decelerating at an approaching stop sign, it will then sound an alert and can also pre-charge the brakes to provide optimum braking force if deemed necessary. This system works in certain Japanese cities and requires Japan specific road markings which are detected by a camera. • In March 2009 the redesigned Crown Majesta, further advanced the Pre-Collision System by adding a front-side millimeter-wave radar to detect potential side collisions primarily at intersections and when another vehicle crosses the center line. The latest version slides the rear seat upward, thus placing the passenger in a more ideal crash position if it detects a front or rear impact.
Volkswagen	The 2011 VW Touareg will incorporate the innovative "Area View" which uses four cameras to detect the Touareg's surroundings and this enhances safety. Moreover, the lane assist function ensures that the vehicle does not stray from the right path; meanwhile, the side assist function warns the driver of vehicles approaching from the rear when changing lanes. Adaptive Cruise Control (ACC) with integrated Front Assist can bring the car to a stop in an emergency and can further tighten seat belts as a precautionary measure.
Volvo	• Volvo's Collision Warning with Brake Support was introduced on the 2006 Volvo S80. This system provides a warning through a HUD that visually resembles brake lamps. If the driver does not react, the system pre-charges the brakes and increases the brake assist sensitivity to maximize driver braking performance. • Collision Warning with Brake Assist was introduced on the 2007 Volvo S80, V70 and XC70. The system provides the same function as Collision Warning with Brake Support, but in addition, provides autonomously partial braking if the driver does not react to the brake assist functions.

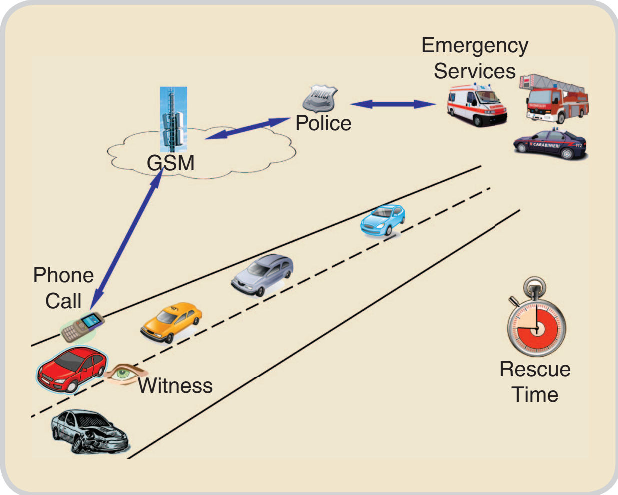

FIG 3 Old method of rescue using a cellular phone when an accident occurred.

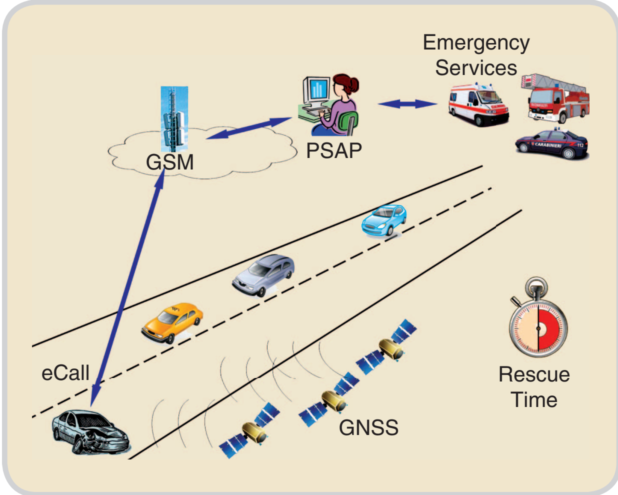

FIG 4 Current method of rescue when an accident occurs (e.g. eCall and OnStar).

Post-crash survivability devices and systems help to minimize the chances of crash injuries or fatalities due to the secondary effects of collision, such as fire. Examples of such devices include: (a) vehicle fuel safety and isolation, (b) fire-resistant materials for vehicle interior, and (c) on-board Black-box based systems (also known as *Event Data Recorder*, EDR). The Black-box technology allows Automatic Crash Notification, and so it is closely related to crash notification systems such as OnStar or eCall. In such systems, cars must be equipped with a kind of black-box that automatically detects the accident when it occurs, records data obtained by in-car sensors, and sends them to the next *Public Safety Answering Point* (PSAP), in order to ask for help. These systems can also be used to determine the cause of the accident or to inform insurance companies. Modern black-box systems also include a built-in camera to make all the recorded information more precise and intuitive. Moreover, most systems record video for a few seconds just before and after a crash. The *National Highway Traffic Safety Administration* (NHTSA) estimates that 85% of new cars will have an EDR (black box system) by 2010 [36].

V. Trends in Emergency Services: From Cellular to VANET-Based

The demand for emergency road services has risen around the world. Moreover, changes in the role of emergency crews have occurred – from essentially transporting injured persons (to the hospital) to delivering basic treatment or even advanced life support to patients before they arrive at the hospital. In addition, advances in science and technologies are changing the way emergency rescue operates. In times of road emergency, appropriately skilled staffs and ambulances should be dispatched to the scene without delay. Efficient roadside emergency services demand the knowledge of accurate information about the patient (adult, child, etc), their conditions (bleeding, conscious or unconscious, etc), and clinical needs. In order to improve the chances of survival for passengers involved in car accidents, it is desirable to reduce the response time of rescue teams and to optimize the medical and rescue resources needed. A faster and more efficient rescue will increase the chances of survival and recovery for injured victims. Thus, once the accident has occurred, it is crucial to efficiently and quickly manage the emergency rescue and resources.

An Automatic Crash Notification system will automatically notify the nearest emergency call center when a vehicle crashes. These call centers will determine the nature of the call and, if it is an emergency, data from vehicular sensors will allow the call center to evaluate if the vehicle has been involved in a collision. Vehicular sensors may indicate that an airbag was triggered, the mechanical impact to the vehicle, whether the vehicle did roll-over, the deceleration history and status, the number of passengers in the car, etc. Knowing the severity of emergencies and their precise locations can save lives readily while utilizing rescue resources efficiently.

The method for seeking help when an accident occurs has changed over the years. Figure 3 shows the old method of accident notification, where a witness of the car accident calls the police for help. The witness gives information about the location of the accident and the fatalities involved. Once the police is notified, they coordinate the rescue effort by alerting the fire department and medical services, summoning for an ambulance to the accident site quickly.

Figure 4 shows the current method of accident notification. When an accident occurs, a call is made to an “answering point” in order to send information about the accident and to ask for help. eCall [37] is one of the most important road safety efforts made under the European Union’s eSafety initiative. eSafety seeks to improve road safety by

Table 6. eCall versus OnStar.

	eCall	OnStar
Automatic Emergency Call	✔	✔
Data Call	✔	✔
Voice Call	✔	✔
Stolen Vehicle Assistance	✖	✔
Navigation Assistance	✖	✔
24 hours Availability	✔	✔
V2V / V2I	V2I	V2I
Communication Technologies	GSM / UMTS	CDMA
Data Transmission Speeds	Up to 12.2 kbps (GSM Full rate)	Up to 9.6 kbps (GSM 2G) Up to 144 kbps (2.5G) Up to 432 kbps (3G)
Range (Coverage Area)	European Union	GM vehicles in the US
Promoter	European Union	GM
Cost	Free	Up to US$300 per year

fitting intelligent safety systems based on advanced electronic technologies into road vehicles. In the event of an emergency, the single European emergency number 112 can be called from all the European Union countries. eCalls are made free of charge from fixed-line or mobile phones. eCall builds on E112 [38], a location-enhanced version of 112. The telecom operator transmits the location information to the *Public Safety Answering Point* (PSAP), which in return must be adequately equipped with a voice-band modem detector, *Minimum Set of Data* (MSD) decoding capabilities, and trained operators to process this data. PSAP and emergency service chains must be capable of dealing with calls coming from an in-vehicle eCall device. They must also be able to process the MSD, including location data, which is automatically transmitted in the eCall, even when voice communication is not possible. The content of the MSD includes: (a) control information, (b) VIN (Vehicle Identification Number), (c) time, (d) latitude, (e) longitude, and (f) direction. The recommended transmission of the MSD between the OBU in the car and the PSAP requires a parallel data transmission with voice. Whether the call is made manually or automatically, there will always be a voice connection between the vehicle and the rescue center. In this way, any car occupants capable of answering questions can provide additional details about the accident.

For eCall to work, several requirements [38] must be met: Firstly, all newly manufactured cars will have to be equipped with eCall devices. In 2005, the European Commission and the automotive industry association agreed to schedule full-scale deployment of eCall service for 2009. eCall devices will be made available as an option for all new cars, starting from September 2009. Secondly, there is a need for the single European emergency number 112 to be operational for both fixed and mobile calls throughout the European Union. Unfortunately, not all EU member states are able to support the full 112 emergency services. Presently, it is working in 12 out of 27 EU member states. Thirdly, emergency centers and all rescue services must be capable of processing the accident location data transmitted by eCalls. For example, ambulances must be adequately capable of receiving and processing these data. Rescue centers must be able to forward all the information to the fire brigade, hospital emergency rooms, etc. In addition, to take full advantage of the voice link to the crashed vehicle, rescue center personnel must be properly trained so as to gather critical information in several languages.

Essentially, by knowing the exact location of the crash site, response time of emergency services can be reduced by 50% in rural and 40% in urban areas. Due to this time reduction, eCall is expected to save up to 2,500 lives in the EU each year, while at the same time mitigating the severity of tens of thousands of injuries. Since eCall can also accelerate the treatment of injured people, there will be better recovery prospects for accident victims. In addition, earlier arrival at the accident scene will also translate into faster clearance of the crash site, which helps to reduce road congestion, fuel waste and CO2 emissions. Overall, it aids in our quest for a greener and safer environment.

A. Comparison of eCall and OnStar

OnStar [39] is an in-vehicle safety and security system created by *General Motors* (GM) for on-road assistance. Both eCall and OnStar systems are, in fact, very similar. A vehicle collision activates on-vehicle sensors, causing an emergency voice call to be initiated. Also, key information about the accident is transmitted. Unlike eCall, OnStar provides an on-road navigation system and assistance in case the vehicle is stolen; it can also remotely unlock vehicles. Nevertheless, eCall is more ambitious since it is expected to support all brands of vehicles in the European Union region, while OnStar is only supported by GM vehicles in the USA. Table 6 outlines the important differences between eCall and OnStar. Future accident notification systems will be more ambitious; intelligent systems will automatically adapt the required rescue resources, allowing the rescue staff to work more efficiently, and reducing the time associated with their tasks.

VI. A View on Future Emergency Services

In the future, our current accident notification paradigm will change with the introduction of vehicular networks. By combining V2V and V2I communications, new Intelligent Transportation Systems will emerge, capable of improving the timeliness and responsiveness of roadside emergency

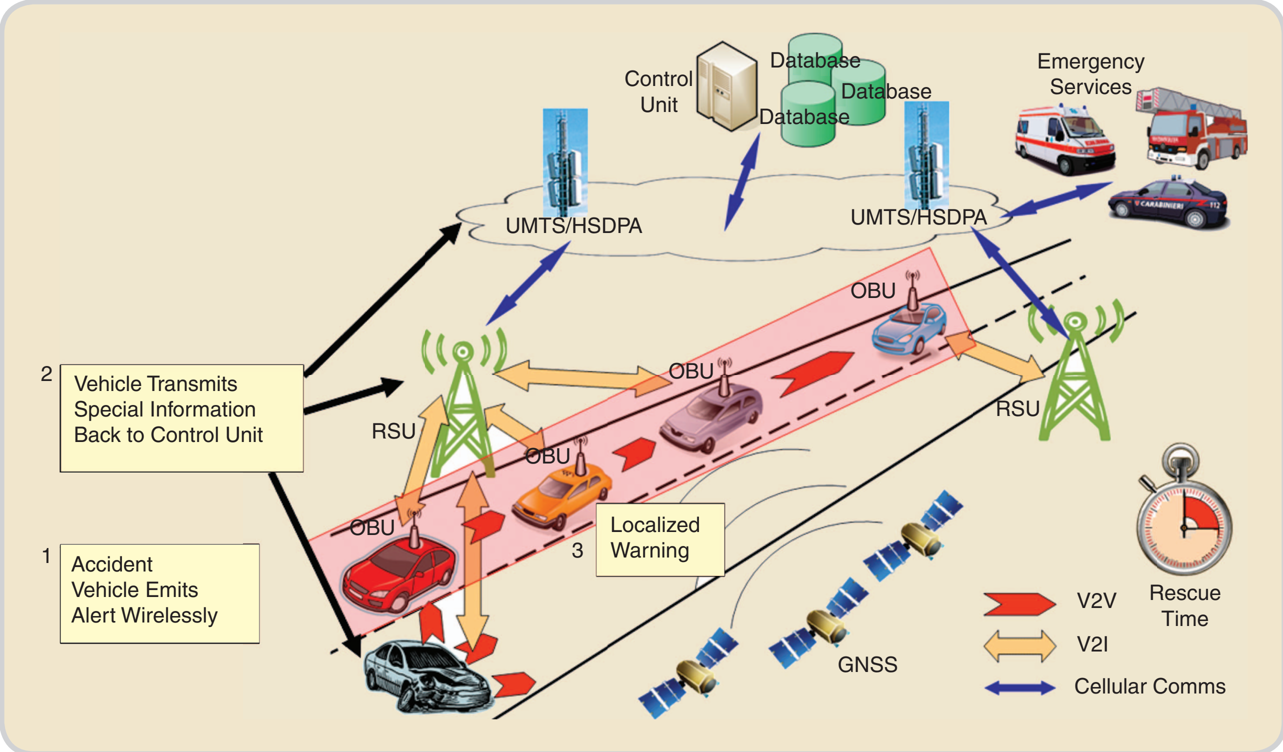

FIG 5 Future emergency rescue architecture combining V2I and V2V communications, utilizing localized alerts and warning, special control information transmission, intelligent databases, and a control unit.

services. As shown in Figure 5, the accident information gathered can be delivered to a *Control Unit* (CU) that automatically estimates: (a) the severity of an accident, and (b) the appropriate rescue resources before summoning for emergency services.

Future emergency rescue architectures will exploit various communication technologies (DSRC, UMTS/HSDPA, WAVE, etc.), empowering road users with both localized (via VANETs) and long haul (via cellular or wide area wireless data) wireless communications. By using vehicular communications, cars involved in an accident can send alert and other important information about the accident to nearby vehicles and to the nearest wireless base station. Thereafter, an intelligent PSAP will gather this information, and channel the most critical data to the appropriate emergency services. Vehicular networks can allow faster notification of any accident occurring on the road (since sensing and propagation of incident information is done on-the-spot in real-time via multi-hop V2V communications). Surrounding vehicles will be immediately notified of the hazard, and such alerts can be further propagated via radio base stations to the core network.

Concerning technology, for any proposal to be successful, it should be compatible with the signaling protocol and air interfaces under existing implementations or standardizations. So, V2V communications might be compatible with the future 802.11p standard, while the V2I counterpart might use any of the 3/4G currently available cellular technologies. The usage of hybrid multi-wireless platforms adds robustness and reliability to the call for emergency help and rescue. In the near future, a community-based effort involving the state departments, public organizations and industry is needed to deploy the required technology and infrastructure to connect all the vehicles on the road and the emergency services.

A. Data for Emergency Use in the Future

Rescue services currently do not have any vehicle-specific information available at the scene of the accident. Rescue manuals provided by some vehicle manufacturers contain too much information to be remembered by rescue staffs under critical situations. The electronic on-board systems currently provide standardized information in a consistent format for all manufacturers. However, the vehicle selection portion should be improved so that rescue staff can select the correct vehicle model using the license plate number or the *Vehicle Identification Number* (VIN) number.

In terms of the vehicle information system, current electronic information systems only offer static vehicle information, which shows the state of different components in the car. Automatic identification of the vehicles involved is only possible in certain countries, for instance via a license plate request (Netherlands, Sweden) or by entering

Table 7. Information to be sent after an accident.		
	Information	Purpose
TIME	Timestamp	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.
	Characteristics of the freight	To provide detailed information about the freight of some special vehicles (such as trucks) to allow rescue services to anticipate the severity of the accident, and to prepare the necessary tools and machinery needed for the accident site.
	Number of passengers	To inform the medical team how many people they need to attend to.
	Features of passengers	To provide description of weight, height, age, diseases, allergies, etc. of affected persons. More information allows for better adaptation to emergency resources needed and better estimation on the severity of those injured. To identify victims.
	Information about seat belts and air bags	To allow for better estimation on the severity of injured people, how the accident had occurred and the severity of the accident.
	Severity of injuries	Severity parameters about passengers, such as if they are conscious or unconscious, bleeding or not bleeding, if they have bone injuries, they can speak or not, etc.
ACCIDENT	Speed and acceleration	To make known the speed and acceleration of the vehicle just before the accident, to estimate the severity of the accident.
	Point(s) of impact	To reveal exactly where the impact(s) has occurred.
	Direction of impact force	If one considers the top of the car as a clock, the direction of impact force can be described as an hour. (12 for front side, 3 for right side, 6 for rear side, etc.).
	Position of vehicle	To reveal the final position of the vehicles after the crash so as to estimate the severity of the accident and the impact on traffic flow.

the VIN (USA). There is no connection to Automatic Crash Notification systems, which should also be capable to select the correct vehicle information and show detailed information about the accident characteristics. In the near future, all these issues shall be addressed.

With knowledge about the crash and related injury severity of occupants, the work of paramedics and physicians can be improved in a significant way. The first step of treatment can be initiated by retrieving information about the status of occupants. Preliminary research work has been done in the USA by the "William Lehman Injury Research Center" [40]. The URGENCY algorithm was developed to predict the injury risk based on observed data from the vehicle or from the paramedic.

The information shown in Table 7 is essential in future emergency services. Basically, the information to be sent after an accident should include the following: (a) the time when the accident has occurred, (b) the location of the vehicle to determine the location of the injured, (c) the characteristics of the vehicle (allowing rescue services to send appropriate equipment to the accident site, and to warn[1] them about the level of complexity and dangers), (d) the characteristics and identities[2] of the occupants, such as the number of passengers, their features (height, weight, etc.), and the severity of their injuries are important information to be transmitted, and finally, (e) the characteristics of the accident, such as the speed and acceleration of the vehicle when the impact occurred, the points of impact, the direction of impact force, and the position of the vehicle after the impact. All these information help in determining the severity of the impact, making it possible to save lives, manage resources efficiently, and enable crashed vehicles to be removed from the site, restoring traffic flow quickly.

The information shown in Table 7 is made compatible with the standard CEN/TS 15722:2009 [42], which defines the data content and format of the eCall messages. Figure 6 illustrates an example SOS Packet Format that includes all the aforementioned information in just 56 bytes. This information will be sent by each damaged vehicle, traveling along the vehicular network to the next RSU in order

[1] It is very important for rescuers to know which critical areas of the vehicle to avoid (e.g. gas inflators) since they are mostly not labeled and might cause hazards for rescue workers.

[2] The identities of the victims will help in determining their medical past history, while permit a fast identification of their family and relatives. The injuries should be coded using the Abbreviated Injury Scale (AIS) [41], an anatomical scoring system that provides a reasonably and accurate ranking of the severity of injury. In the AIS scale, injuries are ranked on a scale from 1 to 6, with 1, 5, and 6 representing minor, severe, and unsurvivable injury, respectively.

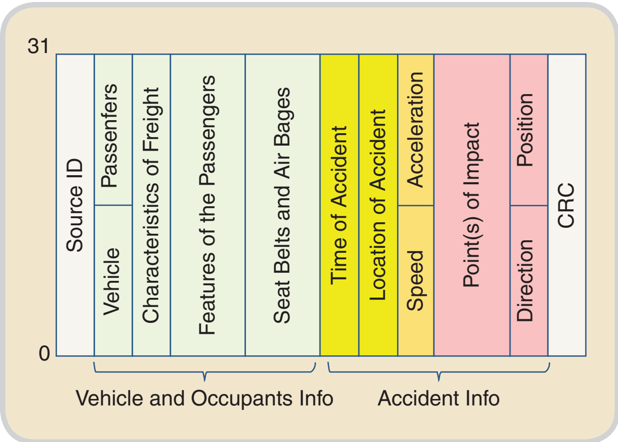

FIG 6 Essential information elements to be transmitted in future emergency services.

to arrive to the *Control Unit* (CU). All these data shall be automatically processed by the CU to decide the resources needed to correctly take care and manage the accident. The CU will compare the data received with previously collected data from a database of accidents, making it possible to predict the severity of injuries, and thus summoning the needed resources for the rescue.

Conclusion

Several research projects led by research institutes and car manufacturers around the world have positively impacted the future of IVC systems. Technologies have clearly contributed to the change in the course of actions to follow after an accident occurs; moving from a simple cellular phone call made by a witness, to the current eCall accident notification system provided in EU. In the near future, accident notification systems will be specially designed for post-collision rescue services. Combining V2V and V2I communications, new Intelligent Transportation Systems will emerge with the capability of improving the responsiveness of roadside emergency services, and allowing: (a) direct communication among the vehicles involved in the accident, (b) automatic delivery of accident related data to the Control Unit, and (c) an automatic and preliminary assessment of damages based on communication and information processing. Future ITS-based emergency services aim to achieve low level of fatalities while significantly improving the response time and efficient use of resources.

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