INFRASTRUCTURE/VEHICLE COMMUNICATION

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ABSTRACT

The paper introduces the potentiality of wireless communications in road safety improvement. New systems based on Vehicle/infrastructure and vehicle/vehicle cooperation are enabled. The results of a recent project "SAFE TUNNEL" and new projects like "SAFESPOT", "GOODROUTE","WATCHOVER", are described. All these research projects are co-funded by European Commission (EC) and witness the strong commitment of EC to support the application of the wireless communication as a key technology for the reduction of the number of road accidents.

1. INTRODUCTION

The growing mobility of people and goods has a very high societal cost in terms of traffic congestion, fatalities and injured people every year.
Several studies shown that the driver is responsible of most of the accidents, mainly for distraction or wrong perception or judgment of the traffic and environmental situations around the vehicle.
In 2001, in the White Paper "European transport policy for 2010: time to decide", European Union set itself the goal to reduce the number of people killed between 2000 and 2010.
The introduction of active (ABS, ESP) and passive (Airbag, Safety belts) safety systems already gave a significant contribution in decreasing the probability of an accident to occur and in mitigating the consequences of accidents on vehicle occupants.
In the past decade, driver assistance systems based on autonomous sensors (e.g. radars, cameras) able to perceive the traffic situation surrounding the vehicle and, in case of danger, to properly warn the driver have been developed and tested in several research projects.
Elaborating the information that this kind of sensors provides, it is possible to reconstruct in real time a scenario of the vehicle surroundings, and provide to the driver warnings and correct indications on the best manoeuvres to do or even automatically drive the vehicle acting on steer, brakes and engine.
In parallel the huge development of wireless communication technologies enabled new possibilities for improving the preventive road safety with system based on cooperation among vehicles and infrastructure and among vehicles and vehicles.
In the cooperative approach the vehicles and the infrastructure cooperate to perceive potentially dangerous situations extended in space and time horizon that will only be limited by the range of the communications.
A pioneering vehicle-infrastructure cooperation system is the one developed in the SAFE TUNNEL project [1]. The vehicle is able to transmit information to a control centre about its

status, the control centre may actuate access control policies, provide optimal speed and distance to be respected and distribute messages in case of emergency. SAFE TUNNEL communication is based on GPRS protocol.
New communication technologies are now available: the cooperative approach envisaged by the SAFESPOT European Integrated Project on "cooperative systems for road safety" will enable the possibility to face most of the road accident typologies.
The key aspect is to expand the time horizon of acquiring safety relevant information for driving, as well as to improve the precision, the reliability and the quality of driver information, and to introduce new information sources. In the cooperative approach the increase of time horizon will allow an extension of the "safety margin", namely the time in which a potential accident is detected before it can occur, from the range of "milliseconds" up to "seconds". This extension, named "green area" will reduce the risk of an accident to occur, as more time will be given to drivers to realise that there is a potential danger and to undertake the appropriate manoeuvres. Other recently started projects based on the cooperative approach are WATCH-OVER and GOODROUTE.

2. THE "SAFE TUNNEL" PROJECT

2.1 The project

Safe Tunnel was an EC co-founded RTD project of the V framework project coordinated by CRF and ended in Dec 2004. It was conceived to contribute to the reduction of the overall number of accidents and incidents inside road tunnels through the introduction of a set of preventive safety measures made possible by the integration of on board vehicle devices and ITS infrastructures using the public wireless network as a communication link.

2.2 The Applications and the results

Four applications have been developed:

- Prognostic (improvement of current vehicle diagnosis introducing the capability to forecast faults).
- Access and vehicle control (communication of vehicle diagnostic data in case of anomalies to a control center through a GSM/GPRS link . The control center may inhibit the access to the risky vehicle or in any case suggest the best action to the driver).
- Telecontrol of vehicle speed and distance (communication of recommended speed and safety from the control center to the vehicle through a GSM/GPRS link and on-board actuation of the received commands. As alternative to cover the unequipped vehicles the feasibility of the Moving spot light system has been performed).
- Distribution of emergency messages to the driver (use of the communication link and an HMI to distribute emergency messages to the driver in order to obtain a safer operation and more easily control the traffic flow in case of emergency).

The technical feasibility of the system has been proven through the implementation and test on real tunnels of two equipped trucks and a control centre.
Furthermore the social impact and cost-benefit analysis has been carried out demonstrating the possible sustainability of the system especially if a political action toward regulation will be done.
To implement the four applications (prognosis, access and vehicle control, telecontrol and distribution of emergency messages) the project has operated at different levels: vehicle,

infrastructure, communication network. An overview of the system features are reported in fig. 1. The GPRS system was chosen for the communication channel.
The system or systems derived from SAFE TUNNEL have been evaluated by important tunnel operators (including Frejus tunnel operators who had a major role in the project) and further analyses are on going in order to exploit the system.
An important step is standardisation that is a key point for such cooperative systems.

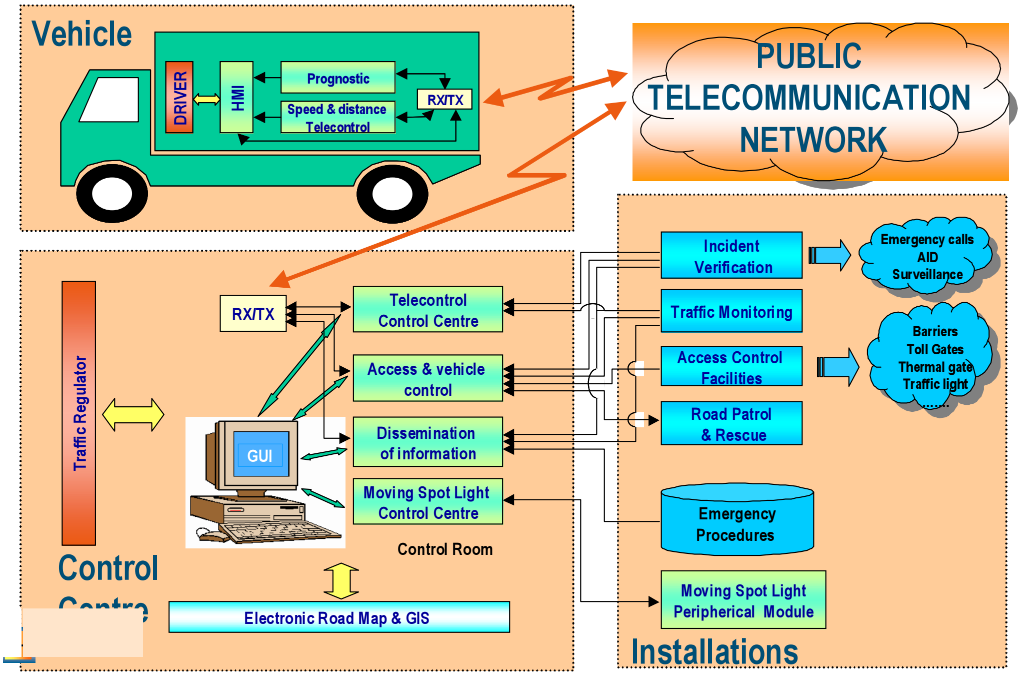

Fig 1 The SAFE TUNNEL system concept

3. THE "SAFESPOT" INTEGRATED PROJECT

3.1 The project

SAFE TUNNEL was a specific cooperative system dedicated to tunnels or restricted areas. In the VI framework program a very ambitious Integrated Project (IP) has been approved and is now recently started (February 2006): SAFESPOT [2].
The project, coordinated by CRF, will last four years and is developed by a consortium of 51 partners including vehicle manufacturers, road operators, suppliers, research institutes and universities. The total budget is about 38 M€ of which 20.5 funded by EC.
SAFESPOT was promoted by EUCAR (European Council for Automotive RD) as part of the "Integrated safety" activity.
The SAFESPOT IP aims to widely extend the cooperation concept not only among vehicles and infrastructure but also using cooperation among vehicles. The objective is to understand how intelligent vehicles and intelligent roads can cooperate to produce a breakthrough for road safety, developing a "Safety Margin Assistant" that:

- detects in advance potentially dangerous situations,
- extends "in space and time" drivers' awareness of the surrounding environment.

The Safety Margin Assistant will be an Intelligent Cooperative System based on vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication that should prevent even most of the emergency manoeuvres.
In SAFESPOT the infrastructure and the vehicles become sources (and destinations) of safety-related information elaborated by a communication and elaboration platform.
The core activities of the project include:

- Development of the key enabling technologies:
  - ad-hoc dynamic networking
  - accurate relative localisation
  - dynamic local traffic maps
  - infrastructure-based sensing techniques.
- Development and validation of cooperative applications like :
  - Hazard and incident warning
  - Safe lane change manoeuvres
  - Road departure prevention
  - Cooperative manoeuvring (e.g. highway merging)
  - Cooperative tunnel safety
- Development and test of several vehicles and test sites distributed in 6 different countries (France, Germany, Italy, The Netherlands, Spain, Swede)
- Definition of Cooperative Systems architecture
- Standardisation
- Business, legal and other exploitation aspects.

3.2 The communication technology

The most challenging technology, that is the heart of the system, is the communication technology. From the network architecture standpoint, roadside components take part to the vehicle-vehicle-infrastructure communication network as “standing” nodes. This means not only to use the same communication platform, but also to be visible and recognisable by any V2V equipped vehicle.
The communication platform should allow the exchange of all relevant data among the nodes in real time and with delay that could be very tight.
The basic requirements and related issues are:

- Reliability, fast, secure, potentially low cost protocols for local V2V and V2I communication
- Candidate radio technology: IEEE 802.11p
- Need for dedicated frequency band for secure V2V and V2I, avoiding interference with existing consumer links
- Aligned to C2C-C and CALM standardisation groups

C2C-CC (Car-to-Car Communication Consortium) [3]is formed and managed by European car-makers in order to develop and standardise solutions for these applications. SAFESPOT will operate in close synergy with this consortium.
CALM Communications, Air Interface, Long and Medium Range (CALM) is an ISO standardisation group defining a communication layer able to virtualise the specific network used (GSM, IPv6, UMTS,…).
The network scenario is depicted in fig.2 . In this figure is named also CVIS, another large Integrated Project, aimed to develop cooperative functions for mobility improvement. CVIS and SAFESPOT will define commonly the system and communication architecture. The final aim is to have a modular system able to manage both applications.

Regarding the future exploitation an action is currently on going sponsored by EC in order to obtain in different European countries a dedicated frequency band in the 5.8 Ghz range, the same adopted in USA.

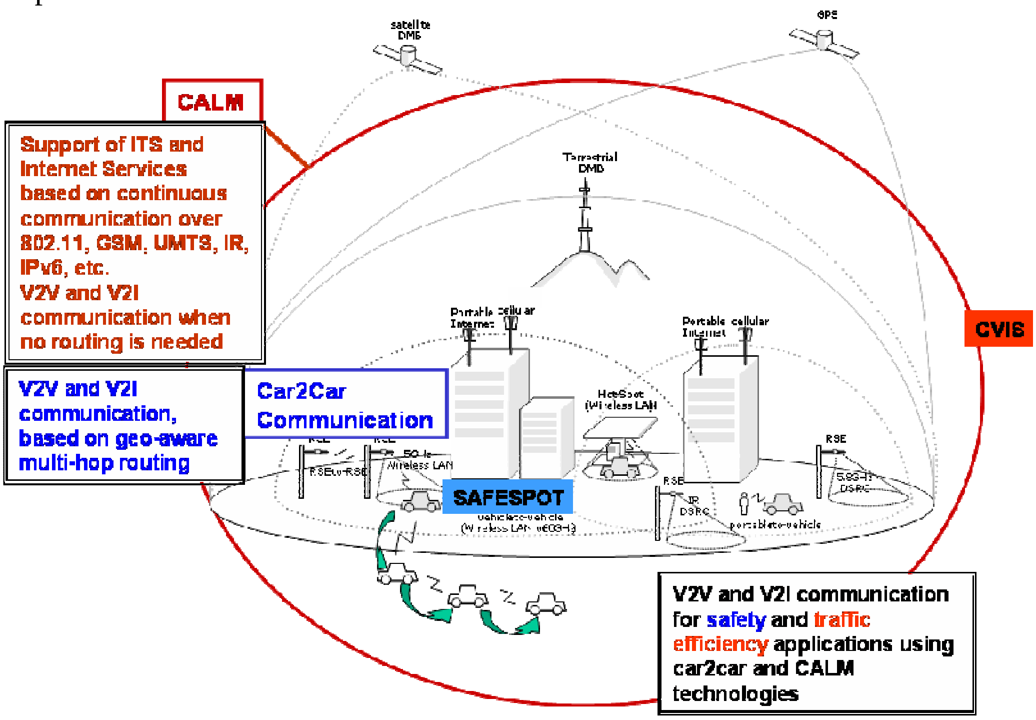

Fig. 2 The communication framework of SAFESPOT.

3.3 The main applications

The SAFESPOT applications have a common set of objectives that aim to:

- improve the range, quality and reliability of the safety-related information available to “intelligent vehicles” by providing and extended co-operative awareness through the real time reconstruction of the driving context and environment (see fig. 3);
- support drivers preventively to the proper manoeuvres in the different contexts;
- optimise the intervention of vehicle controls with respect to critical situations;
- manage existing incidents to minimise further negative safety impact;
- open the development of new safety applications based on the cooperative approach.

These are some examples of the applications that will be developed by SAFESPOT:

Safe lane change manoeuvres: vehicles in the blind spots and vehicles that are intending to change lanes are detected in advance to promptly inform all drivers of relevant vehicles.

Road departure prevention: information on recommended speed is sent from the infrastructure to the vehicles according to road geometry, surface status and traffic conditions. Vehicles equipped with sensors measuring road friction communicate to the other vehicles the presence of slippery roads.

Cooperative manoeuvring (e.g. highway merging): vehicles calculate in real time their relative position and trajectories, when a risky situation and a potential collision is detected, drivers of relevant vehicles are promptly warned.

Cooperative tunnel safety: the infrastructure informs the vehicles about recommended speed and safety distance. The Safety Margin is calculated on the basis of the state and typology of the vehicle.

Hazard and incident warning: transmission of warning messages to vehicles arriving on an area where an accident just occurred. The message can be issued from the infrastructure or

from other vehicles and includes: type of hazard, current location and previous positions, speed, direction.
Safe urban and extra urban intersections: this application requires a very precise computation of the vehicles trajectories and local digital maps of the intersections. The infrastructure delivers information to the vehicles to recognize dangerous situations in time.

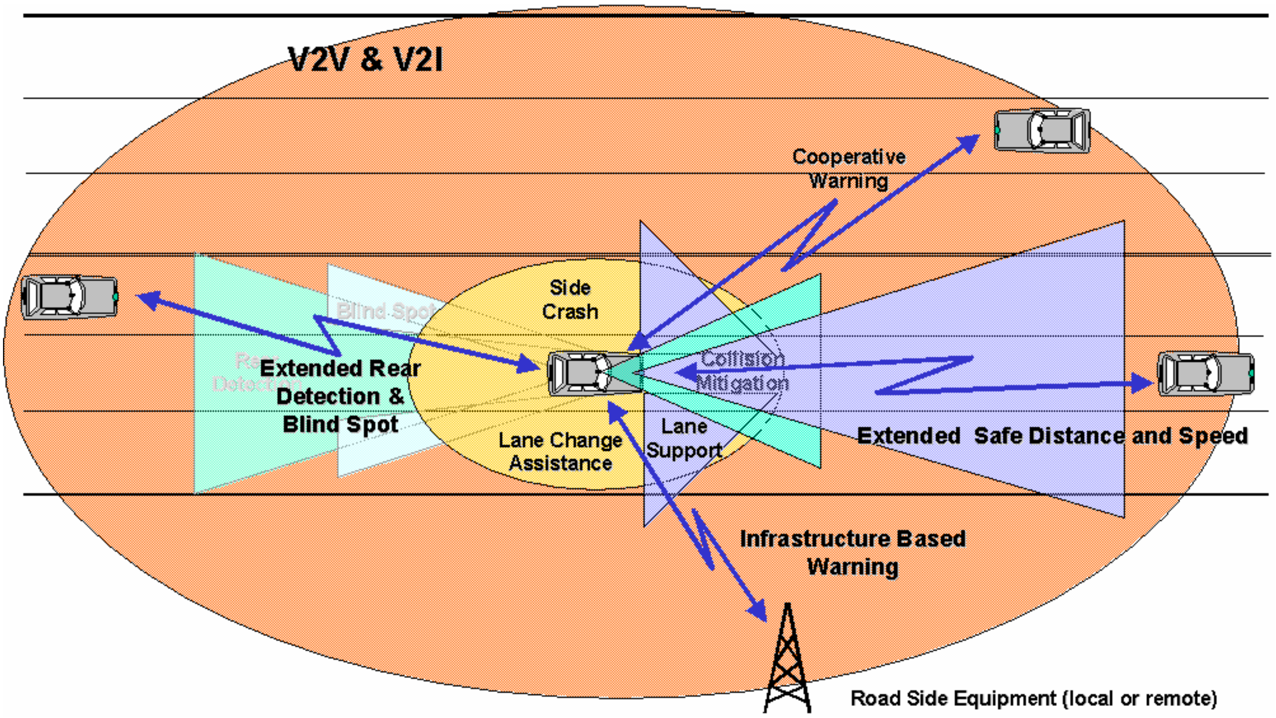

Fig. 3 The "cooperative situation awareness and extended collision warning"

As far as applications are concerned a very important point is the Human Machine Interface. The Safety Margin Assistant should present effective warnings to the driver, namely on time and unambiguously. In the same time the driver mental overload increase should be minimized.

4. THE "WATCH-OVER" PROJECT

WATCH-OVER is a STREP RTD project coordinated by CRF and aimed to design and develop an integrated cooperative system for the prevention of accidents involving vulnerable road users (VRU) in urban and extra-urban areas [5].
The core of the system is the interaction between an on-board module and a user module, which exploits innovative wireless short range communication technologies (as an extension to vehicle autonomous systems). The cooperative low cost platform extends the actual coverage of the state of the art technologies and will be open to integrate localization technologies.
The main functionalities supplied by the WATCH-OVER on-board platform are real-time detection of pedestrians, cyclists, motorcyclists equipped with the WATCH-OVER module, calculation of the relative positioning of the user vs. drivers (relative motion analysis), detection of dangerous situations (external scenario reconstruction, filtering specific situations), appropriate warning to the driver, providing information only in actually dangerous situations. The vulnerable road user module promptly answers to the vehicle's

stimulus, delivering its identification and self-localization parameters, it gives feedbacks to the road user with an appropriate HMI (visual or acoustic warnings).

Previous projects like PROTECTOR and SAVE-U tested a number of technologies for sensing the vulnerable users like far and near infrared systems. 2D and 3D vision, microwave radar. laser radar. Based on these experiences WATCH-OVER will develop and test a second generation of automotive CMOS multi-purpose camera to be used as sensor and will analyze different short range wireless communication technologies for the vehicle and VRU interaction:

- IEEE 802.15.4
- RFID (Radio Frequency Identification)
- UWB (Ultra Wide Band Radio)

5. THE “GOODROUTE” PROJECT

GOODROUTE is a STREP project aimed to develop a cooperative system for dangerous goods vehicles routing, monitoring, re-routing and driver support, in order to minimise the societal risks related to dangerous goods movements, whereas generating the most cost efficient solution for all actors involved in the logistic chain [6].
In GOODROUTE the cooperative approach is used to collect, elaborate and distribute information from vehicles to control centre with a basic architecture close to the one adopted in SAFE TUNNEL.
The basic concept is to create comprehensive distributed data bases and a collaborative platform able to gather and process in real time vehicle and cargo as well as environmental data (road status, unexpected obstacles, weather conditions, population density) that are input to an optimal routing and route guidance system.
Long range and short range vehicle to infrastructure communication linksallow to exchange all relevant data and to provide new routes based on minimal risk.

6. CONCLUSIONS

The paper presented a number of relevant projects aimed to improve road safety using the cooperative approach. The recently started projects were able to collect high investments from partners and European Commission, based on the firm belief that this approach may provide a real step forward in the prevention of road accidents. Common features of cooperative systems are the need of standardisation, the involvement of a large amount of actors from different fields and the consequent need to establish a common understanding, the need to disseminate the underlying concepts to the scientific community, the public authority and common people also considering that the user acceptance is a key factor for this kind of systems. Although some technological challenges and a large number of practical problems must be surmounted to arrive at a real exploitation of the most complex applications, there is a great potential to establish a new way to conceive road traffic, gradually introducing the simpler applications.

7. REFERENCES

More information about the subjects discussed in the paper may be found in the following web sites:

[1] www.crfproject-eu.org
[2] www.safespot-eu.org
[3] www.car-to-car.org
[4] www.tc204wg16.de/Public/CALMintro.html
[5] www.watchover-eu.org
[6] www.goodroute-eu.org