Inter-vehicle communication and cooperative systems: local dynamic safety information distributed among the infrastructure and the vehicles as "virtual sensors" to enhance road safety.

Luisa Andreone
Centro Ricerche Fiat, Tel. +39 011 9083 071, luisa.andreone@crf.it

Michele Provera
Centro Ricerche Fiat, Tel. +39 011 9083 113, michele.provera@crf.it

Abstract

In the past decade research and development efforts have been dedicated to face road safety problems by the development of driver assistance systems based on autonomous sensor technologies that are able to perceive the traffic situation surrounding the vehicle and, in case of danger, to properly warn the drivers. Sensor technologies, essentially based on radar and video sensing, enable the possibility to have in real time a picture of the vehicle surroundings, thus improving road safety by avoiding a number of accidents, or at least by reducing their effects. However, the extent to which advanced driver assistance systems are operable cannot go beyond the operative range of sensors, thus, if from one side an effective real time *"vehicle surrounding situation awareness"* can be reached, the step beyond is represented by the extended coverage (in space and time) that can be offered by a network of cooperating vehicles and by the infrastructure to offer a complete coverage of all different potential dangerous situations and to extend the *"time available for drivers to undertake the proper manoeuvre in case of a potential danger"*.

A number of European initiatives are pioneers in the research and development of the communication technologies applied to road safety (e.g. the CarTALK 2000 project, co-funded by the European Commission Information Society Technology) and in promoting the specification of a European industrial standard for car-to-car communication, supporting the allocation of a dedicated frequency band for active safety applications (activity of the Car2Car Communication Consortium). This publication is to be intended as a brief overview of the main car-to-car and car-to infrastructure cooperation based applications for road safety.

Current activities and future perspectives

In September 2001 the European Commission has presented the "White Paper on European Transport Policy for 2010", which states that the main objective within 2010 is to reduce by 50% road fatalities. In these years all Europe is fostering an integrated safety policy with particular attention to accident prevention, to passive safety, to a proper emergency management, to equip road infrastructure with innovative systems, to exchange information with vehicles and service centres and to the introduction of innovative driving supporting systems to enhance preventive safety.
A brief comparison between the number of fatalities on European roads (around 50.000 every year) and the growing number of cars circulating on European roads (expected to increase by 10% from now to 2010, up to 200 millions cars) gives an idea of the effort needed to meet the goal established on road safety.

A number of running, or just finished projects, are working on the enabling technologies and on the future applications of communication for road safety, for example the European project CarTALK 2000 specified a radio system for inter-vehicle and vehicle-infrastructure communication and developed the basic algorithms for radio ad hoc networks with high dynamic network topologies.

Another example is the German funded FleetNet project that develops a communication platform for vehicle to vehicle communication using multi-hop ad hoc networking.

The specification of a European industrial standard for car-to-car communication and the allocation of a dedicated frequency band for active safety applications in Europe are essential requirements for the deployment of the communication technologies as driving information and support systems to enhance road safety.
For this reason, the goal of the C2C Communication Consortium is the establishment of an open European industry standard for inter-vehicle-communication systems, also including communication among vehicles and roadside infrastructure components.
Road safety applications foreseen are: traffic safety and efficiency, e.g. hazard warning in congested areas and high throughput in merging areas, driving comfort, e.g. enhanced ACC adapted to the traffic situations. Additionally, also infotainment applications can be implemented using the same communication system, e.g. roadside internet access, gas payments, etc.
For instance vehicles that are in an accident or are approaching a traffic jam, turn on their warning lights, if these vehicles are equipped with a car-to-car communication system they can send out a warning message to the surrounding traffic to avoid collisions. The communication can be initiated by an airbag-sensor, switching on warning lights automatically and initialising the communication to other vehicles whose relative position and driving direction is relevant to the critical area.

Fig. 1 – Vehicles and infrastructure will be the sensors of safety related information: vehicle dynamics, road friction, smart dust sensors embedded in the roads, infrastructure environmental sensors will create the network of real-time safety information of the future.

The safety added value of the future activities will be to look for the “combination” of the information from the vehicles and from the infrastructure. The focus will be on research and development activities regarding the identification of co-operative solutions that can firstly be applied to the most critical areas whose danger is quantified by statistical data.
The key aspect will be to expand the time horizon for acquiring safety relevant information for driving, as well as to improve the accuracy, the reliability and the quality of such an information, using the vehicles and the infrastructure as sensors.

Thus, the support from car to car communication and from road infrastructure is needed to provide:

- earlier information, complementary to those available from active safety sensor based systems;
- more precise (in time, space and quality) information on driving situations;
- new and complementary information on driving situations.

Typical situations that can be managed by a network of vehicle-to-vehicle and vehicle-to-infrastructure communication extending the operative range of vehicle sensors are for example:

- adverse weather conditions, reduced visibility, bad road conditions;
- obstacles that cannot be seen by autonomous sensors (e.g. behind narrow curves);
- vulnerable road users detection in urban scenarios.

The key aspects of future research and development are the definition of the specific usage scenarios, namely the detailed analysis of the problems to be solved and the definition of the sources of information. The focus will be on the enhancement of technologies for detection of poor visibility and of road conditions as well as on the use of all available data on vehicle dynamics to derive driving conditions in real time, while from the infrastructure side sensors with lifelong autonomous power supply embedded in the road surface have the highest potential.

From the side of the communication technology some of the main issues are:

- the definition of the network layer for seamless multihop vehicle-to-vehicle and vehicle-to-infrastructure communication, with particular attention to the reliability for safety-related communication;
- the definition of how to bridge the gap between vehicle-to-vehicle and vehicle-to-infrastructure communication via a proper communication management.

One of the main relevant key issue is the localization inside “ad hoc networks”, namely the relative localization among vehicles that are close to each other so that a group of vehicles, inside the range of the radio transceiver, will build an “ad hoc dynamic network”. Research will have to address the problem to have a good relative localization, in real time, using local radio communications, also in view the future possibilities that are expected to be enabled by the availability of the Galileo satellites constellation.

All the available information will be stored in local temporary maps, distributed among the infrastructure and the vehicles; these temporary maps will become “virtual sensors” used by the vehicles to know in advance, for example, that the traffic is blocked behind a narrow curve.

Another challenge will be the definition of how to manage the time period where “non equipped vehicles” will still be the largest part of the circulating fleet. Smart equipment will have to be designed and developed to extend the benefit also to non-equipped users, starting the implementation in the most risky areas.

The driver is the first user of all safety related information, thus human machine interfaces for predictive information are needed as cooperative (vehicle to vehicle and to infrastructure) systems will be designed to become aware of a dangerous situation much in advance with respect to the sensing capabilities of the driver and of vehicle sensors. The current development of the integrated human machine interfaces, like the activities carried out by the AIDE Integrated project co-funded by the European Commission within the 6th Framework initiatives, will have to cope also with the availability of “predictive” information that from one side represent an enhancement of “real time information” and on the other side increase the complexity of the on board information systems. The interaction with the drivers will be based on real time identification of driving behaviour together with the availability of traffic and environment situation awareness.

Car-to-car and car-to-infrastructure cooperation for road safety

The objectives referred to the local area in which cars will cooperate to enhance road safety are:

- to improve, as an extension of autonomous intelligent systems, the range, the quality and the reliability of safety related information;
- to create applications for *"extended cooperative awareness"* by means of real-time reconstruction of the driving context and environment;
- to open the development of new safety applications based on the cooperative approach;
- to optimise the intervention of vehicle controls with respect to critical situations.

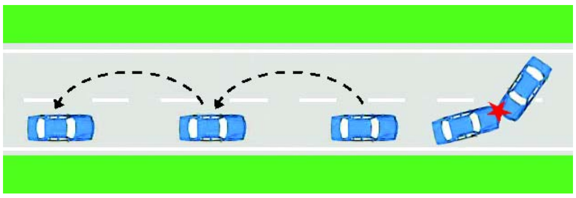
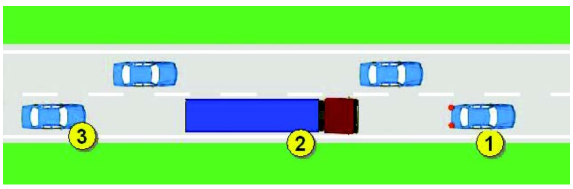
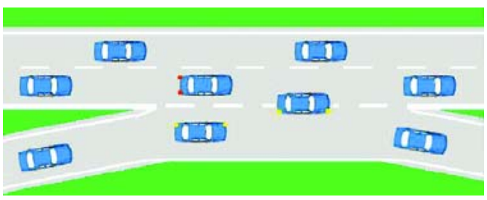
These applications are characterized by a complete reconstruction of the driving context and road environment using in combination on-board sensors data and cooperative system information (ad-hot vehicles network concept):

- to support drivers preventively to allow them to undertake the proper manoeuvres in the different contexts;
- to prevent the critical situations or to manage them correctly;
- to enhance the intervention of the vehicle systems.

Typical accident situations and related scenarios are:

- lane change manoeuvre assistance;
- frontal collision prevention in two-ways roads;
- rear-end collision prevention in critical road segments like in tunnels;
- lateral collision prevention in a black spot such as a junction;
- road departure prevention in a black spot such as a dangerous bend;
- signalling of static obstacles in a black spot such as road work.

In the following table some examples of scenarios and applications are listed.
[Source: the CarTALK 2000 project]

	**Information and warning functions** vehicles transmit warning messages when a critical situation (vehicle breakdown, high traffic density, dangerous road surface conditions, etc.) is detected.
	**Communication-based longitudinal control** vehicles can anticipate braking manoeuvres when an invisible vehicle (n. 1) beyond the direct predecessor in front (n. 2) is braking.
	**Co-operative driving manoeuvres** by exchanging information up to simple trajectory plans, critical situations can be foreseen and solved by the vehicles themselves.

The “dynamic vehicle network” and the “vehicle to infrastructure network” are conceived to extend the operative range of the actual on-board vehicle systems and to allow the driver to receive the information on possible manoeuvres or to continue to maintain the same behaviour avoiding the critical situation.

The context of vehicle to infrastructure based applications is relevant in road scenarios in which roadside components can take part to the car-to-car and to the car-to-infrastructure communication network as “standing” nodes. In this case the objectives are:

- to increase road safety for vulnerable users;
- to improve the range, quality and reliability of the safety-related information available to intelligent vehicles (which are already equipped with autonomous on-board systems) by providing co-operative awareness through the real time reconstruction of the driving context and environment.

The applications focus will be on:

- smart signalling for safety enhancement;
- hazard and accident warning;
- safe urban intersection;
- speed alert and road departure prevention.

The expected impact of these applications is on supporting drivers and other road users in taking preventive action, thus avoiding accidents and on managing the time frame just after an accident occurred, to reduce the possibility that other road users are involved.
In general, the scenarios covered by this kind of applications will focus on “static black spots”, namely potentially dangerous road segments like tunnels, bridges intersections, road merging, etc.

Conclusions

The cooperation among the vehicles and the infrastructures, including local traffic management enabled by local control units distributed in the risky areas, will allow the implementation of integrated strategies that will rely on the cooperation of new generation of equipped vehicles and roads.
Novel traffic control techniques will be investigated and implemented distributing the intelligence of the application to road-side and low-cost infrastructure with the aim to achieve high level of efficiency and robustness of safety related information. Distributed and autonomous road side equipments in communication with the “network of communicating vehicles” will enable the possibility to react promptly and reliably to safety critical conditions providing the information to drivers “on board” and “off board” thus addressing the equipped and non equipped vehicles.

Acknowledgements

The authors of this paper would like to acknowledge the C2C-C Consortium, the CarTALK 2000 project consortium, coordinated by DaimlerChrysler, EUCAR and the working teams of the project proposals focused on the items of “cooperative systems for road safety” presented in the call for proposal addressing the research area on “eSafety - Co-operative Systems for Road Transport”.

Activities and Applications of the vehicle to vehicle and vehicle to infrastructure communication to enhance road safety

Luisa Andreone
Centro Ricerche Fiat (Italy)
luisa.andreone@crf.it

CENTRO RICERCHE FIAT

ROAD ACCIDENTS AND FATALITIES IN EUROPE
Reduction from 1980 to 2000,
but still 50.000 fatalities occur per year in the Europe-25

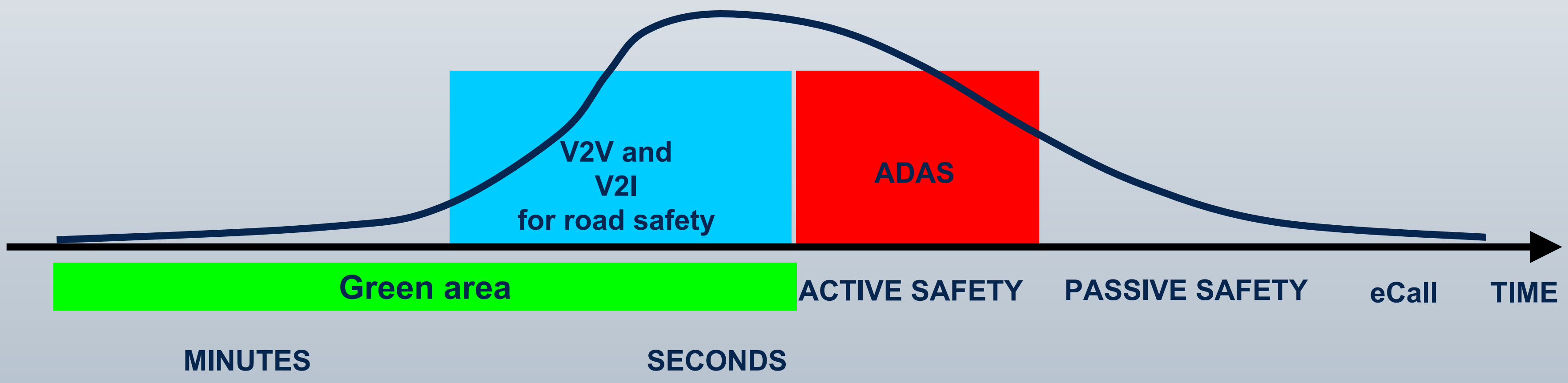
- **Reduction of road accidents from 1980 to 2000: - 8 %**
- **Reduction of fatalities in road accidents from 1980 to 2000: - 39%**

[Source IRTAD-OCSE]

ROAD SAFETY: the applications

The operability of **ADVANCED DRIVER ASSISTANCE SYSTEMS** can reach a real time “vehicle surrounding situation awareness”, but cannot cover all scenarios.
The step beyond is the extended coverage (in space and time) that can be offered by a net of cooperating vehicles and by the infrastructure to offer a complete coverage of all different potential dangerous situations and:

“to extend the time available for drivers to select and undertake the proper manoeuvre in case of a potential danger”

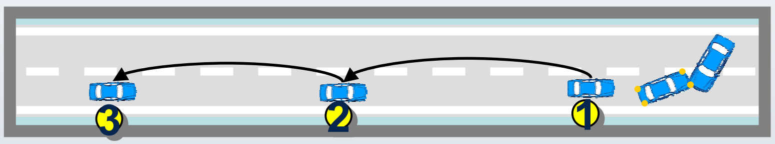


IMPACT ON ACCIDENT REDUCTION

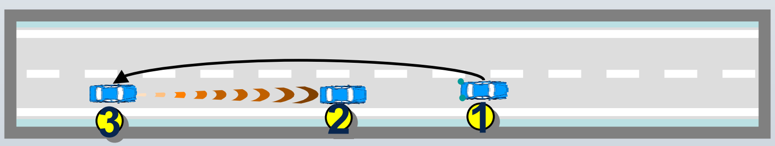
Vehicle to Vehicle Communication
the CARTALK project

(funded by the European Commission within the 5th Framework Programme)

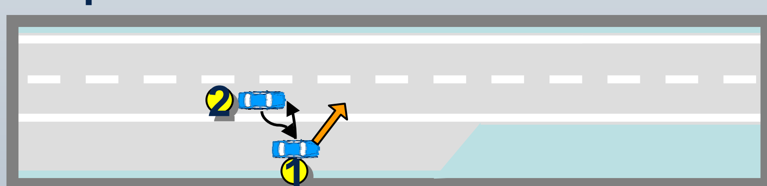
Information and warning functions

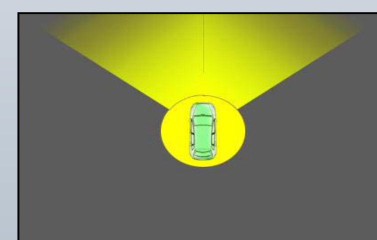


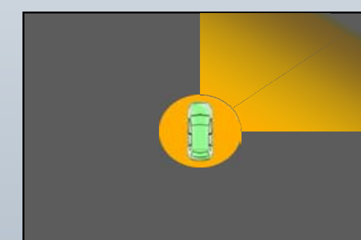
Communication-based longitudinal control



Cooperative driver assistance





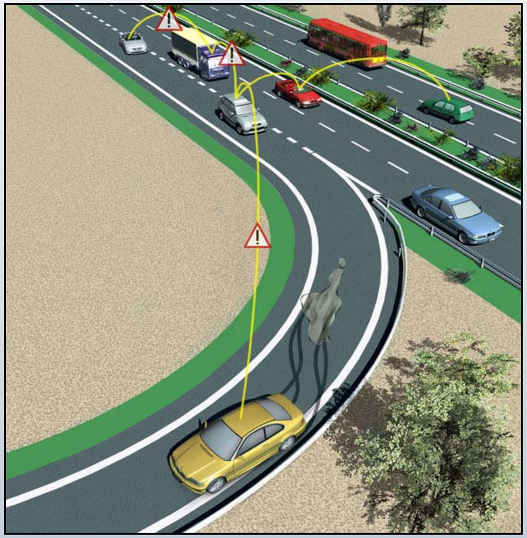


Project Partners

DaimlerChrysler, Centro Ricerche Fiat, Siemens, Robert Bosch GmbH, TNO, Uni. Köln, Uni. Stuttgart

ROAD SAFETY: V2V-I applications

The **COOPERATIVE DRIVING APPLICATIONS** for road safety are characterized by a complete reconstruction of the driving context and road environment using in combination on-board sensors data and cooperative system information (ad-hoc vehicles net).



Typical **related driving scenarios** are:

- overtaking and lane changing assistance
- frontal collision prevention
- rear-end collision prevention in critical road segments (e.g. in tunnels)
- lateral collision prevention in a black spot (e.g. a junction)
- road departure prevention in a black spot
- signalling of static obstacles in a black spot like road work
- prevention of collisions with vulnerable users
- hazard and accident warning
- safe urban intersection
- speed alert and road departure prevention in curves

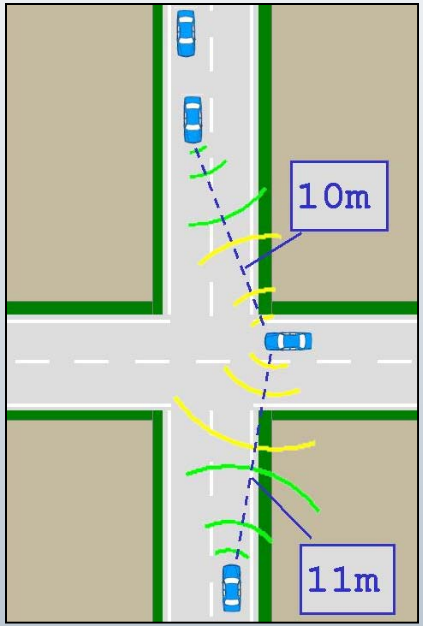
ROAD SAFETY: V2V-I Enabling Technologies

The **COOPERATIVE DRIVING APPLICATIONS** main building blocks:

- ✓ the vehicle and the infrastructure as "sensors"
- ✓ the architecture and the **enabling technologies** for:

ad hoc dynamic vehicle-vehicle-infrastructure network

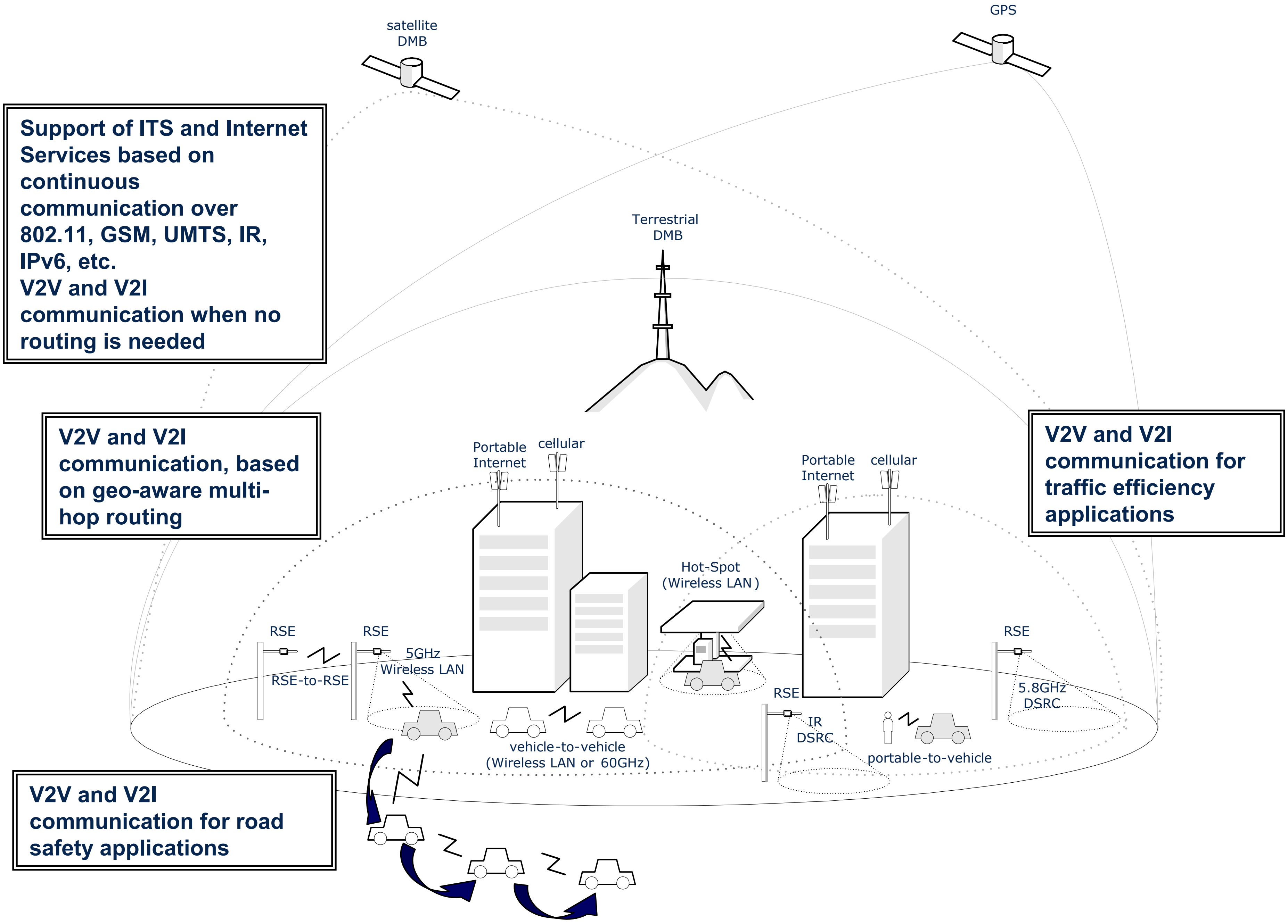
- development of flexible, dynamic data transmission protocols
- data security, anonymity and integrity issues
- routing, multihop forwarding and geo-cast techniques in vehicular ad hoc networks
- geographical addressing mechanisms



co-operative relative localisation

- relative vehicle localisation via ad hoc network
- GNSS-based relative vehicle localisation
- vehicle localisation via landmarks registered in digital maps

COOPERATIVE VEHICLES AND ROAD INFRASTRUCTURE



C2C Communication Consortium
Mission and Objectives

- to create and **establish an open European industry standard for Car2Car** communication systems based on wireless LAN components and to **guarantee European-wide inter-vehicle operability**
- to enable the development of active safety applications by specifying, prototyping and demonstrating the Car2Car system
- to promote the allocation of a royalty free European wide exclusive frequency band for Car2Car applications
- to push the harmonisation of Car2Car Communication standards worldwide
- to develop realistic deployment strategies and business models to speed-up the market penetration

C2C Communication Consortium
Working group on standardisation activities

- Preparation of the communication standard based on the specifications of the Working Groups
- Observation of current standardisation activities and existing standards
- Presentation of the project results to the European standardisation bodies
- Proposals and negotiations for possible frequencies in contact with CEPT etc.

ROAD SAFETY:
the new cooperative paradigm in Europe

from autonomous intelligent vehicle to cooperative intelligent system

INTELLIGENT VEHICLE ADVANTAGES

Reduction of the electro/electronic vehicle ADAS system complexity

↓

Reliability enhancement, extended anticollision function and Costs reduction

↓

Function spreading on all vehicles

INTELLIGENT ROAD ADVANTAGES

Reduction of Infrastructure Cost/Complexity

↓

Safer use of the Infrastructure

↓

Accidents reduction (impact on traffic flow optimisation)

ROAD SAFETY: benefits for all actors

Drivers will drive vehicles equipped with more “robust” driving assistance systems thanks to dynamic information about the traffic, the road and the environmental conditions from the vehicle net and from the infrastructure.

Car makers will open new market opportunities offering on the market new functions for safer vehicles at sustainable costs as the “intelligence” will be distributed. The level of complexity of vehicles will be decreased, compared to autonomous solutions.

Suppliers will meet the challenge of new market opportunities being ready to offer fully developed technical solutions and actively driving the evolution in terms of concept generation, and standardisation.

Road operators and public authorities will improve road safety on motorways and urban roads via a combination of infrastructure and vehicle systems that will collect and transmit in real time traffic/weather and accident information to all road users and to traffic information centres.

SHORT TERM MARKET SCENARIO PERSPECTIVE: Year 2010

Identification of the key influencing factors

for the introduction on the market of vehicle safety systems

- **Risk of product liability**
- **Financial risk (recall, image problems)**
- **Usability of safety systems**

Source: the RESPONSE Project

[FORD, Centro Ricerche Fiat, AUDI BMW, DaimlerChrysler, PSA, Bosch, ERTICO, Miller Insurance, TNO]

SHORT TERM MARKET SCENARIO PERSPECTIVE: Year 2010

CENTRO RICERCHE FIAT

The MATRIX of Cooperation for a sustainable deployment of On-Board Safety Systems

AREAS of INTERVENTION ACTORS	Risk of Product Liability 1. Design defects 2. Production defects 3. Instruction failures	Financial Risk 1. Recall campaign 2. Image problems	System Usability
OEMs	●	❍	●
Road Operators			❍
Suppliers	●	❍	●
Public Authorities	●	●	

Luisa Andreone luisa.andreone@crf.it

REFERENCE

Luisa Andreone C2C Steering Committee Member
Tel. +39 011 9083071 e-mail luisa.andreone@crf.it

Michele Provera C2C Technical Committee Member
Tel. +39 011 9083113 e-mail michele.provera@crf.it

Centro Ricerche Fiat
Telematic Department
Strada Torino 50, 10043 Orbassano, Torino, Italy