INFRASTRUCTURE-BASED CO-OPERATIVE ARCHITECTURES: HOW SAFESPOT DEALS WITH DIFFERENT ROAD NETWORK AREAS.

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ABSTRACT

The SAFESPOT Integrated Project, started in February 2006, is a research project co-funded by the European Commission, under the strategic objective "eSafety Cooperative Systems for Road Transport". Its goal is to understand how intelligent vehicles and roads can co-operate to produce a breakthrough in road safety. The system should extend in space and time the driver's awareness of the surrounding environment, using wireless communication to enable vehicle-to-vehicle and vehicle-to-infrastructure co-operation through the IEEE 802.11p protocol. This paper presents the conceived architecture solutions, aimed at fulfilling the SAFESPOT system requirements in every kind of environment within the road network.

KEYWORDS: safety, vehicle, infrastructure, cooperation, environment

INTRODUCTION

The permanently growing demand for mobility of people and goods has led to huge socio-economic costs in terms of fatal accidents and accidents with serious injuries. Thus, it is a matter of common knowledge that one of the major objectives of the European Union is to halve this number of accidents by 2010. The SAFESPOT (1) Integrated Project (6^{th} European Framework Program), which was launched in February 2006, involves 52 partners form different European countries: car manufacturers, road operators, research institutes and automotive suppliers. The aim is to increase, from the range of "milliseconds" up to that of "seconds", the time margin for the detection of a potentially dangerous event. By combining data from vehicle-side and road-side sensors through vehicle-to-vehicle and vehicle-to-infrastructure communication, the driver is warned on time to avoid the accident.
At the beginning of the project, a detailed road accident analysis and a study of co-operative systems state-of-art led to important choices:

- the use of the 802.11p protocol (2) for wireless communication at 5.9 GHz,
- and the integration with other systems using the CALM architecture (3).

In particular SAFESPOT Subproject CoSSIB aims at designing co-operative applications running on a processing unit placed on the road infrastructure. In this context, different architectural solutions for the roadside infrastructure were sought, depending on area topology, traffic volume and availability of existing equipment. Three main areas were identified having their own peculiar requirements and thus deserving to be treated separately: urban roads, rural and secondary roads, and motorways. In the following sections, after a presentation of the overall concept, the implementation on these areas will be discussed.

SYSTEM OVERVIEW

In an infrastructure based approach, the SAFESPOT system can be seen as composed of the following functional modules:

- *sensing peripherals*, including infrastructure sensors and vehicles equipped with additional sensing systems, the latter exchanging data with the infrastructure;

- *alert peripherals*, including both Variable Message Signs (VMS) and all SAFESPOT equipped vehicles;

- *data processing and fusion unit*, which is responsible for the collection and processing of data coming from multiple sensing peripherals; it is placed on the road side but can be detached from the main roadside unit;

- *Local Dynamic Map (LDM)* which is a map database containing both static and dynamic data of the surrounding area (4); it is a fundamental component in SAFESPOT as it represents the link between the data acquisition and processing systems and the applications; here we specifically refer to the LDM placed on the roadside infrastructure, but also each equipped vehicle includes its own LDM;

- *applications*, representing the intelligence of the roadside infrastructure; they evaluate the safety margin on the basis of the local situation - inferred by querying the LDM – and they decide the type of warning to be sent and the alerting modality (5);

- *message manager*, responsible of generating, storing and routing messages; it is the interface to between the roadside unit and the vehicles via the Vehicle Ad Hoc Network (VANET), which is based on wireless communication.

Moreover, in SAFESPOT- SAFEPROBE Subproject, vehicle systems are developed which observe their environment by using advanced sensing systems (e.g. radar). The detected risk can be transmitted to the other vehicles - including vehicles that are equipped only with the communication system - and also to the roadside infrastructure. Although this feature is not specifically analysed in CoSSIB, it is crucial, since it allows the deployment of partially equipped infrastructure in places where some sensors are not available.
The following table synthesises four types of scenarios, each one including a group of use cases having the same detection sources and warning strategy. Although this classification is at very high level (going into more detail, different use cases avail of different strategies) it is fundamental for the choice of the appropriate technologies.

<table>
<tr><th>Scenario</th><th>Risk detection source</th><th>Warning strategy</th></tr>
<tr><td>1</td><td>Roadside infrastructure by means of roadside sensors</td><td rowspan="3">Infrastructure unit displays warnings on roadside alert systems, and sends warnings to equipped vehicles via short range communication</td></tr>
<tr><td>2</td><td>Roadside infrastructure by means of roadside sensors and vehicle sensors</td></tr>
<tr><td>3</td><td>Roadside infrastructure by means of roadside sensors, vehicle sensors and external sources (like Traffic Information Centres)</td></tr>
<tr><td>4</td><td>SAFEPROBE vehicles</td><td>Through an ad hoc communication network involving equipped vehicles, the warning is sent to roadside units and to other equipped vehicles</td></tr>
</table>

Table 1. High level classification of risk detection sources and warning strategies

Focussing on scenarios 1, 2, and 3, it can be said that they are potentially compatible with all driving environments. Nevertheless, scenario 3 imposes certain constraints in the functionalities, in terms of power supply, communication network and already existing equipment.

THE URBAN AREA

The urban environment is very dense and complex, with many intersections managed by traffic light controllers (6). Beyond the vehicles, it includes different types of users like pedestrians or bicycles. Because of a very high traffic load in these areas, the vehicle flow is sensitive to any kind of disturbance. Irregularities influence the flow of traffic in a wide area of the network and increase the risk of accidents. For instance, 45% of urban accidents in Italy (7) occur in the proximity of crossroads. The main reason is that the driver approaching an intersection has a high mental workload. He has to decide the driving direction, he has to keep an eye on several points to avoid any misjudgement and as well he has to take care of pedestrians, cyclist and other potential vehicles crossing his way.

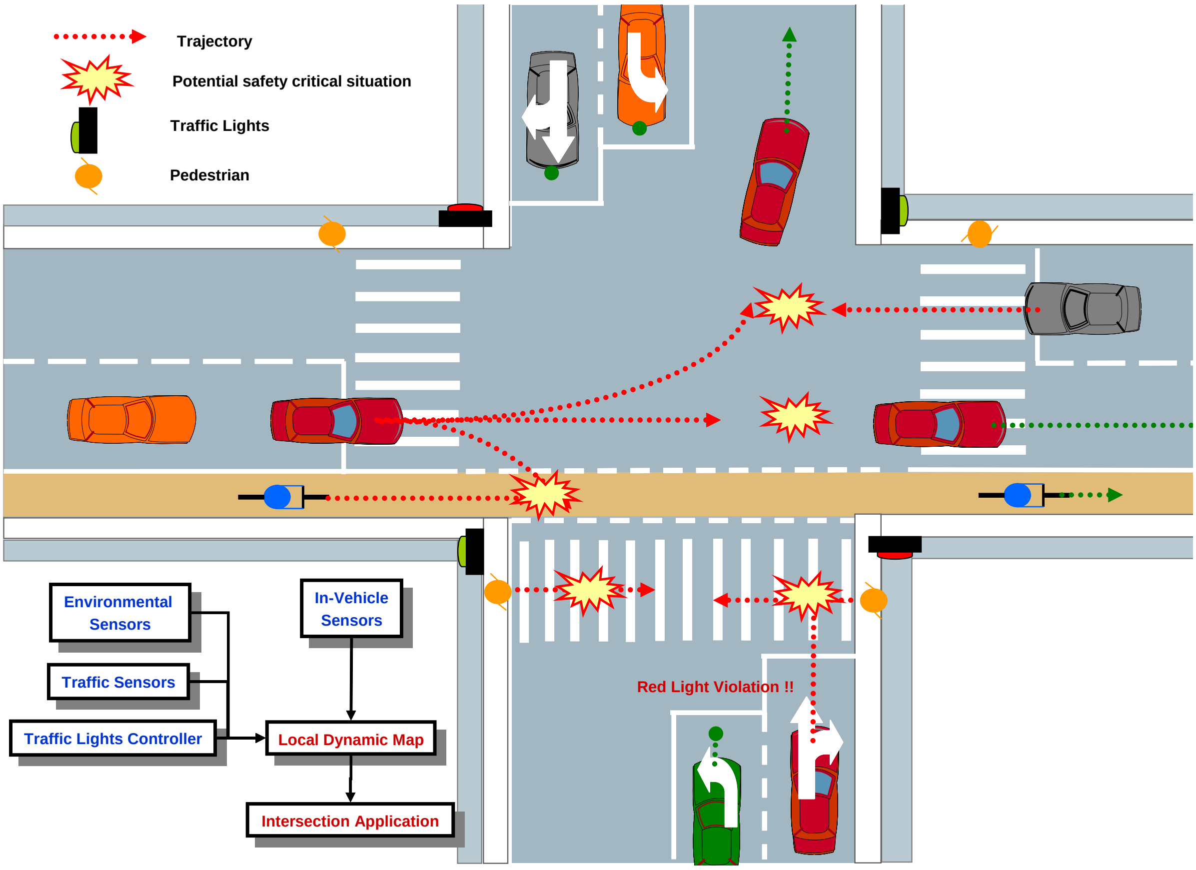

Figure 1. Scenario at an urban intersection

The whole intersection should thus be monitored, to detect every safety-critical situation. Since the presence of buildings often disables the use of direct communication between vehicles coming from different directions to the intersection, a co-operative system is necessary, involving communication devices and sensors from the infrastructure. Data provided by vehicle and roadside sensor systems have to be combined and provided to the application running at the intersection's roadside unit.

A complex co-operative architecture is under development, integrating also the already existing sensor systems and traffic light controllers. In this way the trajectories of vehicles in the monitored area can be computed and predicted, and potential hazards can thus be detected. Then, a proper alerting strategy is issued, involving infrastructure-to-vehicle communication, control of traffic lights, and possible actuation of VMS panels. This strategy is crucial, since the addressing of warning to all or to a selected driver at the intersection depends strongly on the type of situation.

THE RURAL AREA

The rural and secondary road network is huge and heterogeneous, including also mountains, forests and low density of population areas. The latter often limit the range of the Global Positioning System and the communication systems. Moreover, in some countries, the driver can cover in a short period several road segments belonging to different local authorities, and the level of road services may vary significantly.

Another specificity of the secondary and rural roads is the potentially low availability of energy points. Some architecture components need energy to handle communication and data computing. Solutions such as solar battery or power-independent sensors shall be envisaged, but they may set limits to the functionality of components. The most critical case in terms of architecture requirements is represented by the areas which do not allow easy provision of energy and communication means. For these areas, a specific solution with a minimum data transfer, very short range communication and auto-power supply is being investigated.

The extreme solution in case of complete lack of infrastructure sensors could be to rely entirely on the Vehicle Ad Hoc Network (VANET), and consider the infrastructure unit only as a repository and delivery point of messages to incoming vehicles.

THE MOTORWAY AREA

On motorways, the majority (87%) of lethal accidents occurs on straight segments (8), but some parts of the network, like bridges or tunnels, are also critical. In these points, managing an accident is difficult and often no alternative road is available. This leads to unacceptable traffic jams in case of accidents.

Thus, in motorways, the SAFESPOT applications must deal with two main types of situation:

1. static "black spots", where particular road configurations (e.g. tunnel, bridge, heavy traffic sections, complex exchange) lead to a certain accident probability or a critical need of supervision from the road operator, due to the potential consequences of an accident;
2. the remaining road network, composed of long straight segments and smooth curves where accident causes are mostly independent of the infrastructure.

In static black spots additional equipment is installed to improve road safety. Typically, the car density can be monitored with regularly spaced inductive loops or even cameras, where more detailed information is required. VMS are deployed to allow displaying variable speed limits and other dynamic information. This equipment is costly to install since cables have to be buried under the carriageway, connected to a road side cabinet and powered. Moreover, installation generally requires traffic interruption or at least limitation, and therefore has to be performed at night. Thus, a high density of such equipment cannot be envisaged along the entire length of the motorways. This means that, for the straight parts of the motorways that are not identified as static “black spots”, regularly spaced communication devices will be deployed, without providing a full coverage on the section, and no additional sensors will be installed. In these sections the applications will mainly be based on the information provided by equipped vehicles that gather and keep the information between two road side units. Vehicles will mainly use the VANET to transmit information on uncovered areas while it is also possible to use the appropriate road side unit if one is available upstream of the detected event. Figure 2 depicts the proposed architecture for the motorways.

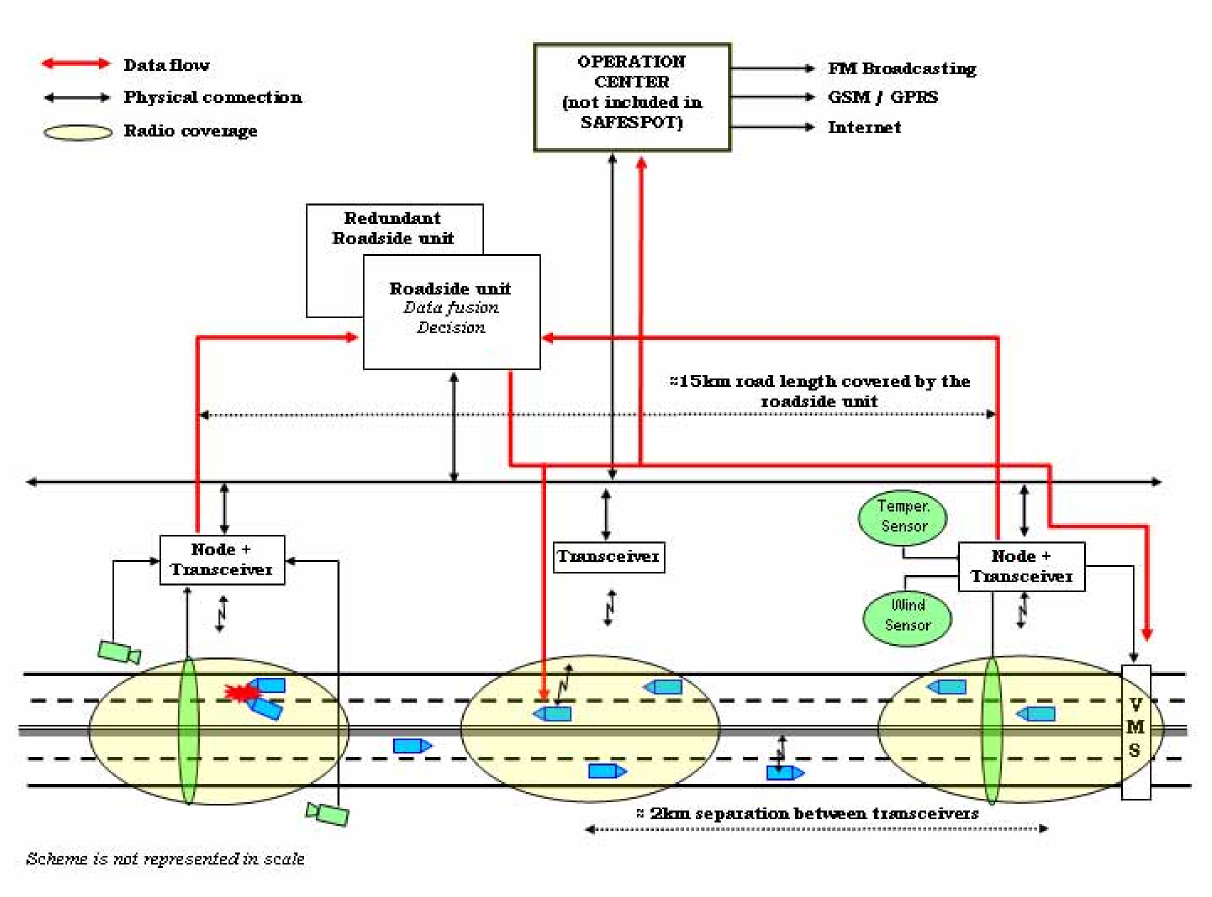

Figure 2. System deployment on a motorway

CONCLUSIONS

Due to the obvious heterogeneity of the network in terms of density of traffic, average speed, risk of accident, presence of intersections, availability of power supply or link to information centre, the architecture for the road side of the SAFESPOT system proposes various levels of equipment.

The system is based on the use of the 802.11p protocol, but it must be compatible with other systems. Therefore, the SAFESPOT architecture is a subpart of the CALM architecture, and compatibility with other European projects like CVIS, COOPERS, ECALL, APROSYS or PReVENT are considered.

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