ROAD TRAFFIC INFORMATIC (RTI) SYSTEMS USING SHORT-RANGE MOBILE COMMUNICATIONS

Mark Chanine, Bernhard Walke

Communication Networks, AACHEN University of Technology
D-5100 Aachen, Germany
Fax. + +49 241 84964

ABSTRACT

The future employement of new technologies, such as advanced control theory, neural networks and AI (Artificial Intelligence) in automotive electronic control and road traffic control gives the possibility of defining safety related and advanced driving applications aiming at a direct support of the driver in the operational driving task he is carrying out and in different road traffic situations. The major objective is to enhance significantly safety, comfort and efficiency in road traffic.

Such applications require intelligent, accurate and reliable systems with short-range and real time communications at high data rates which must be made available to a large number of mobile stations. This paper explores a practical mixture of studies and measurements results as needed for the introduction and realization of such systems.

INTRODUCTION/BACKGROUND

The increasing demands from drivers for safety and comfort has made it necessary for the automotive industry to make further progress in automotive electronic control (1). There is significant activitiy in Europe (PROMETHEUS), Japan and USA on various systems and all are advancing toward the realization of an intelligent vehicle control system in which all electronic subsystems, such as anti-lock brakes control, engine controls and steering control, interactive co-operate. The vehicle will become more sophisticated and increases driver's control ability, enhances vehicle maneuverabilty, provides more safety and comfort and offer the possibility of the realization of advanced road traffic driving applications.

Recently, there has been a major change in transport infrastructure construction programmes. With the aim of meeting more the needs of different road users and owners, which are sometimes in conflict, correctly balanced control strategies have been considered. To be effective in this aim it is essential that an intelligent global system is adopted in which road transport environment communication systems are integrated. Here too, there is significant activity in Europe (DRIVE, RACE), Japan and USA on various systems integration. An extensive standardization will speed the exploitation of the results worldwide.

Both activities, "Intelligent car" and "Intelligent road" are still under research and development. In this paper, the author intends to discuss safety dedicated SRMCS (Short Range Mobile Communication Systems) specially, which are of present and future interest to the other activities.

SAFETY DEDICATED SYSTEMS

Drivers' abilities are limited. Driving experience, age, stress and other factors are the reasons. The use of knowledge about the human mechanism in an appropriate system is assumed to improve drivers' performance.

Drivers do not have sufficient information or assistance. The driving task is becoming more and more complex and the level of accidents increases steadily. The introduction of "Intelligent Road" and "Intelligent Car" systems enhances driving conditions generally. (Fig. 1)

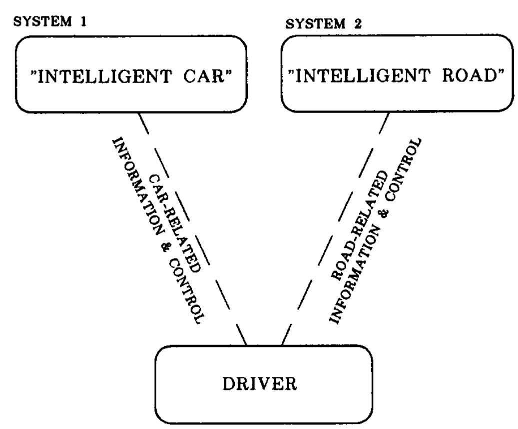

Fig. 1 Intelligent Car, Intelligent Road.

The increasing amount of information does not facilitate the task of the driver or improve the driving comfort. Co-Driver systems which are able to collect information about driving conditions and car status, to evaluate the potential implications for the operational driving task which the driver is carrying out, and to assist the driver in critical road traffic situations ease drivers' tasks and increase safety.

The main objective of safety dedicated systems is the elimination of accidents. The coordination of the operational driving task which a driver is carrying out, with other drivers in his direct vicinity avoids letting critical road traffic situations emerge, which lead most to accidents. SRMCS builds the means for a Co-Driver system enabling such cooperation where vehicles and roadside infrastructure communication systems exchange information, (Fig.2).

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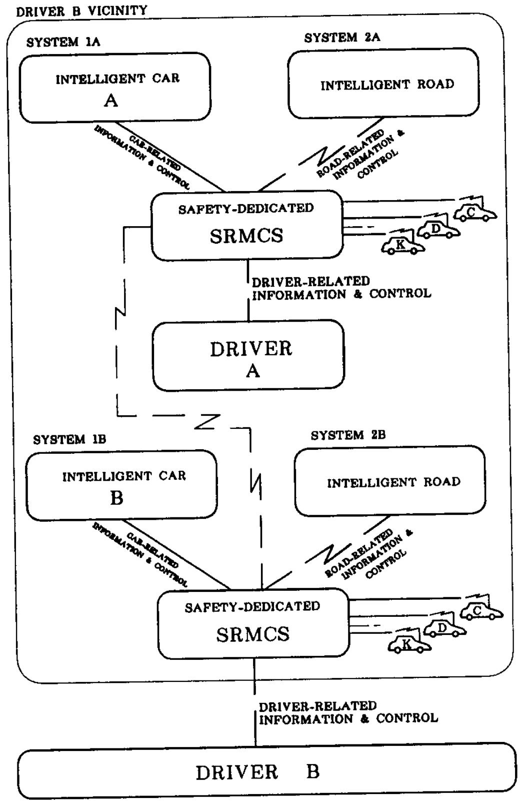

Fig. 2 Safety-Dedicated Systems.

The progress from system-related to driver-related information & control and the integration of road traffic related communication systems including driver's own car, in one environment, makes the configuration presented in (Fig. 2), driver friendly. A clear and an adaptive design of a Man-Machine-Interface is essential for safety dedicated SRMCS, (Fig. 3).

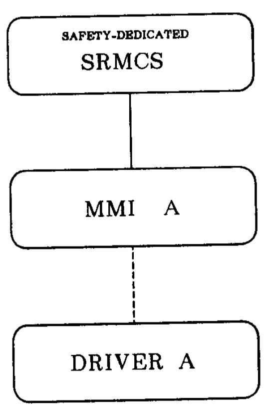

Fig. 3 Adaptable Man-Machine-Interface.

Land mobile radio communication systems and public data networks are considered as a crucial element of any future intelligent road system. Wide-ranging exchange of safety related information is necessary in emergency situations, such as accident situations. The integration of SRMCS in an intelligent road traffic communication system enables the exploitation of all existing means for a better and efficient realization of very important road traffic applications and ensures a global coverage. In addition, the communication ability of less equipped vehicles increases in using well equipped vehicle systems in special and well defined road traffic situations. (Fig. 4)

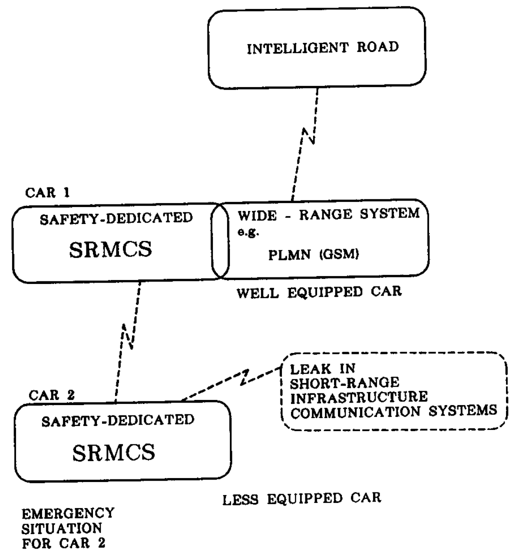

Fig. 4 Global Coverage.

Integrated sensors and systems for monitoring road and weather and means by which driver unfitness and inattentiveness are detected, complete the features of an intelligent Co-Driver system. Road Traffic Informatic safety dedicated systems need "Intelligent Road", "Intelligent Car" and "Intelligent Co-Driver" systems together. (Fig. 5)

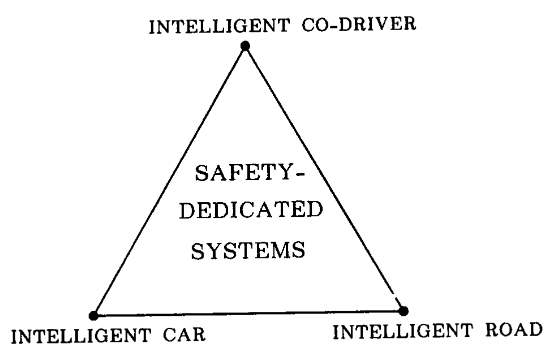

Fig. 5 Safety-Dedicated Systems need Intelligent Car, Road and Co-Driver.

SYSTEM APPLICATIONS

On-board safety dedicated SRMCS provide the driver with advice and enable real-time rescue procedures. More advanced systems are capable of intervening in driver operational driving tasks, e.g. collision avoidance situations. Traffic scenarios such as lane access, lane keeping, merging, overtaking, intersection crossing, parking and avoiding critical situations, need dedicated and intelligent applications to coordinate the safe carrying out of the scenarios. Providing the driver with more information in critical traffic situation is not safe. Therefore, any application realization strategy and philosophy should enable the driver to be advised in advance about the safety of the operational driving task which he intends to carry out,(Fig. 6), or what preventive measures he has to take in order to avoid the emergence of critical traffic situations, (Fig. 7). Interventions should be accepted by the driver and also covered by legislative measures beforehand. The advice provided to the driver has a self-protective character. It helps the driver to take preventive measures in order to protect himself from other vehicles or obstacles in his direct vicinity, so that if each driver succeeds in protecting himself, no accidents should occur.

Wide-range integrated real-time applications shorten rescue processes in informing rescue authorities, police, fire-brigades and road traffic management centers about locality and situation conditions.

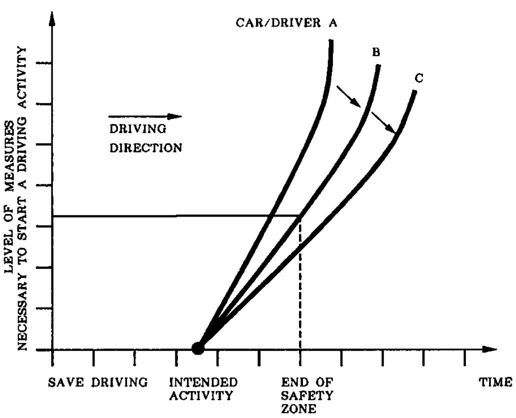

Fig. 6 Safe Driving Activity.

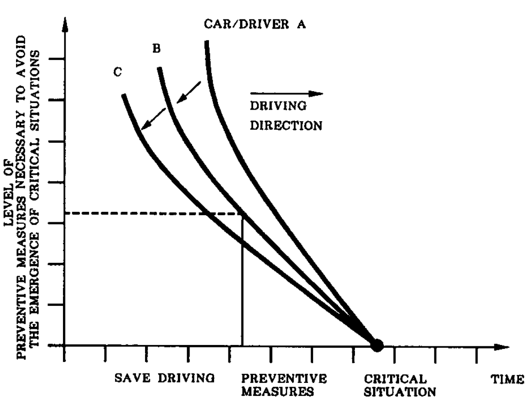

Fig. 7 Critical Situation.

REALIZATION

Other SRMCS road traffic applications, such as automatic debiting or dynamic route guidance are more infrastructure dependent. The main differences to safety related applications are the communication requirements and the network topology. A choice between the different proposed systems to cover different ranges of applications and the adoption of a single network technology to cover all short-range applications to the exclusion of the rest, based upon the current state of knowledge, is not possible at present. A convenient concept is the integration of different systems using different technologies, (Fig. 8).

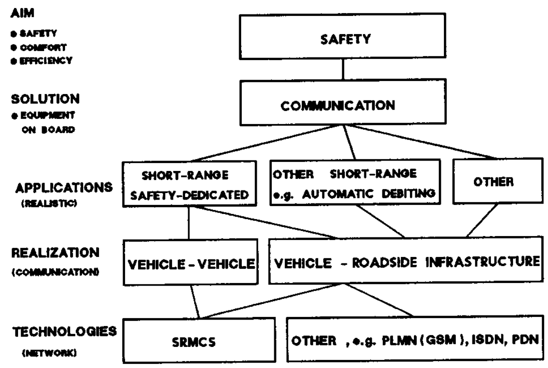

Fig. 8 System Realization.

SYSTEM PARAMETERS

The vehicle vicinity includes vehicles, cyclists, pedestrians, animals and obstacles. Vehicles which could collide with each other or influence the each others driving behavior belong to the same vicinity. Vicinities change with traffic conditions and vehicles in the same vicinity, traffic situation, coordinate their operational driving tasks in exchanging information about their status, behavior and monitored road traffic conditions. An on board-computer evaluates all information and generates advice or intervention commands.

The adaptive transmission range of safety dedicated SRMCS covers vehicle's vicinity as well the available roadside infrastructure systems. The transmission range for a given traffic situation depends on the traffic situation itself, the high dynamic network characteristics such as traffic velocity and density, vehicle performances such as maximum speed, accerelation and braking, driver's capabilities such as reaction time, etc.

The system frequency spectrum allocation belongs to the main technological constraints an engineer faces when designing a radio link communication system. Hardware availibility, economic factors and general regulations belong to the same set of constraints. The extensive availibility of a frequency spectrum and the propagation characteristics of the electromagnetic waves in a frequency area, such as reflection and point of resonance, influence the selection procedure significantly. The chaining character of SRMCSs distributed network architecture with complete dezentralized organization makes frequency reuse necessary and of great importance.

The system channel capacity depends on the number of vehicles within a transmission range and the transmission medium characteristics. Reliable and individual communication links and random and successful channel access are mandatory. The configuration of system channel capacity with the maximum number of vehicles of the worst case traffic situation makes channel access in an ideal situation reliable. Signal interferences, which are dependent on frequency, atmospheric phenomena and conditions, diffusion ways, fading, shadowing and generally nonideal transmission characteristics, restrict channel use and force already allocated channels to be changed.

The system frequency band, a fundamental physical transmission limitation, depends on channel capacity, amount of data to be exchanged and the system real time constraints. Vehicles and roadside infrastructure communication systems exchange static, dynamic and situation specific data. The vehicles' mobility and the permanent changes in network structure limit dynamic data validity and make a reliable check-mechanism to control the correctness of received data necessary. The real time constraint requests priorities in data exchange and a periodical data update which is a function of many factors such as maximum speed, acceleration and deceleration and traffic conditions.

The system data set contains private, resident, acquired and processed datas. Resident datas are fixed or adaptable to driver or vehicle features or characteristics. The vehicle acquires data from other vehicles, roadside infrastructure systems and the neighborhood. The vehicle monitors its neighborhood with different technologies such as sensors and artificial vision. Intelligent on-board computers process data for informative or/and control related applications, (Fig. 9).

The system operates in "real-time" for data acquisition, computing and control. Computing includes, time-based computing to key its operation to time in the real-road-world; sensor-based computing to monitor and measure different states of the traffic process (passiv); actuator-based computing to control or manipulate certain driving performance process (active); and finally -interactive computing to monitor responses which contain data with certain time constraints e.g. position direction and speed of a mobile station in road traffic.

STATIC	DYNAMIC	PROCESSED
VEHICLE: IDENTITY TYPE SIZE PERFORMANCE	VEHICLE: POSITION SPEED DIRECTION STATUS	VEHICLE: POSITION DIRECTION, SPEED LIMITS, RISKS CONTROL,MONITOR
ROADSIDE: IDENTITY,POSITION	ROADSIDE: STATUS	ROADSIDE: MONITOR
ROAD: IDENTITY TOPOLOGY GEOMETRY REGULATIONS	ROAD: SURFACE WEATHER TRAFFIC EMERGENCY	ROAD: CONDITIONS LIMITS RISKS MONITOR
DRIVER: DESTINATION PRIVATE, ABILITY	DRIVER: ACTIVITIES STATUS	DRIVER: MONITOR ADVISE
EQUIPMENT: TYPE	EQUIPMENT: STATUS	EQUIPMENT: MONITOR, CONTROL

Fig.9 Basic Information.

SYSTEM ARCHITECTURE

Referring to the open system interconnection (OSI) basic reference model, layers 5-7 are application dependent. Layer 4 establishes reliable connections and serves as the applications interface to the networks. Layer 3 handles internetworking and routing and is network dependent as well as layer 2 and 1. Layer 2 transfers data reliably and provides access methods for transmission. Layer 1 handles bit transmission via communication media.

With the diversity of expected road traffic applications, short-range communication systems using various technologies are expected to become available. Existing and standard communication systems operating at radio frequencies such as GSM in Europe, will have to be considered for applications requiring wide range communications. In order to secure the maximum degree of integration, it is necessary that a diverse range of applications be supported by different physical communication bearers. The number of physical communication bearers has to be kept small. Layers 1-3 of standard communication networks are well defined and can only be integrated through internetworking in case of common applications. A common road traffic transport protocol ensures global connectivity between all applications realized from different sides and different communication networks.

Short-range applications differ in communication requirements. We are convinced that, safety-related applications require a connectionless point-to-multipoint communication facility due to vehicle mobility and changes in environmental conditions and real time constraints. Only the availibility of actual and valid vehicle, road and driver related data makes the decision regarding advice or intervention possible. Vehicles coordinate their driving activities with other vehicles and roadside infrastructure in the same vicinity directly. Automatic debiting requires a connection-oriented communication facility in order to ensure financial transfers accurately. Other short-range applications such as dynamic route guidance require other facilities. SRMCS are still under development and a common Logical Link Control protocol, enabling the required short range communication facilities, eases the share of communication links, speeds the introduction of different short range applications and presents more means for new applications and also saves costs, (Fig. 10).

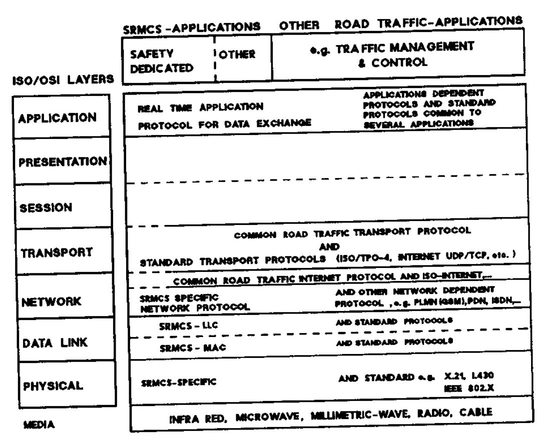

Fig. 10 System Architecture and Protocols.

The mobility of vehicles requires decentral and dynamic channel oriented media access control protocols (6). The requirement for reliable communication makes channel reservation and reliable channel change due to interferences and handover necessary. Localised communication satisfies other applications such as road pricing.

The early stage of technology development for short range communication applications and the lack experience in their performance in real-world operating environments means that the selection of a suitable physical bearer is not possible at present.

A simulation tool, SIMCO (SImulation of Intelligent Maneuvring and COmmunications) based on realistic measurements has been developed to study the complex relationship between driver, system and environment of safety dedicated SRMCS. Other short-range applications are being taken into consideration (7).

EARLY SYSTEM

The step-by-step introduction of safety-related systems is necessary due to human factors issues such as acceptance, or behavioural changes implications, which are as important as technical feasibility. Therefore, applications supported by an early system provide safety-related information to the driver and to rescue authorities, traffic management centers, etc,(Fig 11). The objectives of an early system are:

. Avoidance of accidents.

. Elimination of surprise effects.

. Reduction of the severity of accident related consequences.

. Shortening emergency help procedures.

. Contributing to traffic management and traffic control.

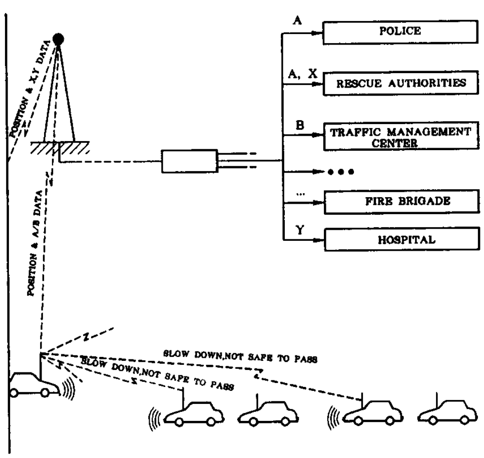

Fig. 11 Early System, real-time applications.

CONCLUSION

Safety in road traffic can be achieved by monitoring and improving the performance and ability of the driver. Safety-dedicated systems inform the driver about the safety of his intended driving activity and advise him what preventive measures he has to take in order to avoid the emergence of a critical traffic situation. They enable real-time road traffic rescue operations.

Boundary conditions such as human behavior and acceptance make the step-by-step introduction of such systems necessary. The understanding of human mechanism in interpreting, combining and reacting to happenings will be necessary for more advanced systems.

Safety in road traffic is very important to car manufacturers, an indicator of living standards for nations and beneficial to drivers and other vulnerable road users. The design of systems which could cover ranges of applications speeds and eases the introduction of advanced safety applications.

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