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VEHICLE COMMUNICATIONS: A SHORT SURVEY

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ABSTRACT

Inter-vehicle communications (IVC) consists in a real application of vehicular ad-hoc networks (VANET) and is part of Intelligent Transportation Systems (ITS). An overview of IVC is presented. To guarantee IVC effectiveness, attention must be paid to one of the most important component of the system: the driver and the way he/her receives crucial information. A brief summary of the communication issues is presented.

KEYWORDS

Inter-Vehicle Communication (IVC), Vehicle-to-vehicle Communication (V2V), Vehicle-to-infrastructure Communication (V2I), Intelligent Transportation System, (ITS), Advanced Driver Assistance Systems (ADAS).

1. INTRODUCTION

In recent years, wireless networks had a tremendous growth in many human activities. Mobile phones, electronic toll collection and wi-fi hot spots are some of such applications. Developments in vehicle-to-vehicle communication (V2V) and vehicle-to-infrastructure communication (V2I) have also increased. While considerable research has been done regarding fully autonomous vehicles (e.g. cybercars) (Parent 2005) human factor will continue to play a fundamental role in daily traffic. Platooning, collision avoidance and similar applications have been object of research. To allow safety messages exchange between vehicles, some rule making was done, granting exclusive use of specific wave frequencies. Nevertheless, in the ADAS context, the whole communication system will be useless if information isn't passed adequately to the key element of the process: the driver.

2. INTER-VEHICLE COMMUNICATIONS OVERVIEW

IVC communications consist of wireless communication mechanisms allowing vehicles to communicate with other vehicles or with infrastructure. It may use infrared beams or radio waves, such as VHF and microwaves. The later operates in broadcast and are very promising in IVC use.

In the USA, Federal Communications Commission defined DSRC (Dedicated Short Range Communication) in 5.9 GHz band. It provides up to a 1 km range and allows communications between vehicles moving up to 160 km/h. It has low latency (50ms), 8 priority levels, one control channel (ch.176) and six service 10 MHz channels (Figure 1), one of which of high availability for security purposes (ch.172). It is based on IEEE 802.11p standard to Wireless Access in Vehicular Environments (WAVE) and is defined by ASTM E2213 standards (new 802.11p), IEEE 1609-1 (Resource Manager), 1609-2 (Security Services for Applications and Management Messages), 1609-3 (Network Services), 1609-4 (Medium Access Control) and IEEE 1556 (Security). In EU, the International Organization for Standardization (ISO), under the Technical Committee TC204 is working in a similar standard to ensure European-wide inter-vehicle interoperability.

There are two main components of a DSRC communication system: an On-board Unit (OBU) and a Roadside Unit (RSU) (Jones 2005). The RSU announces to OBU approximately ten times per second, emits warning messages and safety status messages and informs about the applications supported on each channels. An OBU listens on the control channel, authenticates RSU digital signature and executes safety applications first.

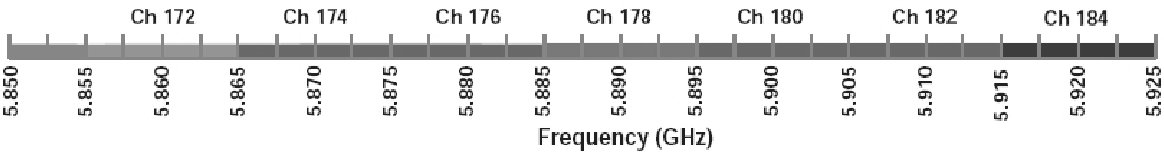

Figure 1. DSRC frequency allocation

Then, it switches channels, executes non-safety applications and listens again on the control channel. DSRC's low latency, licensed frequency, high availability and security mechanisms makes it the right choice for safety messages transmissions. In order to maintain driver's privacy, OBU's addresses are randomized, RSU application announcements are authenticated using Public Key Infrastructure and the messages are encrypted at link level.

3. IVC ARCHITECTURE MODELS AND TECHNOLOGIES

Much work has been done concerning architecture models. One of them, Communication Air Interface Long and Medium Range (CALM) (Williams 2004), ISO TC204/WG16 standard, defines the requisites to ensure interoperability between diverse communication system, with the use of IPv6 and Network Mobility (NEMO) technology (Rabel et al. 2005), which extends the MIPv6 concept (Raya and Hubaux 2005), to support mobile networks. CALM combines GPRS/UMTS with Mobile Wireless Broadband, DSRC, infra red and millimeter waves, along with position information from GPS or Galileo devices, to enable continuous communications, using the media available the most efficient way.

United States Department of Transportation, through Research and Innovation Technology Administration (RITA) defined a National ITS Architecture, providing a common structure for the design of intelligent transportation systems. The model of ITS functions (logical architecture) presents a functional view of the ITS user services. The physical architecture partitions the functions defined by the logical architecture into classes and subsystems. Figure 2 presents a top-level diagram of the proposed physical architecture (Architecture Development Team 2007a), where 22 subsystems (white rectangles) are distributed among four classes: Travelers, Centers, Vehicles and Field. Communication requirements between those subsystems are supported by four communication types, shown as ovals in Figure 2: wide area wireless, fixed-point to fixed-point, vehicle-to-vehicle and dedicated short-range. Table 1 presents some of the technologies that each of the above communication types may use.

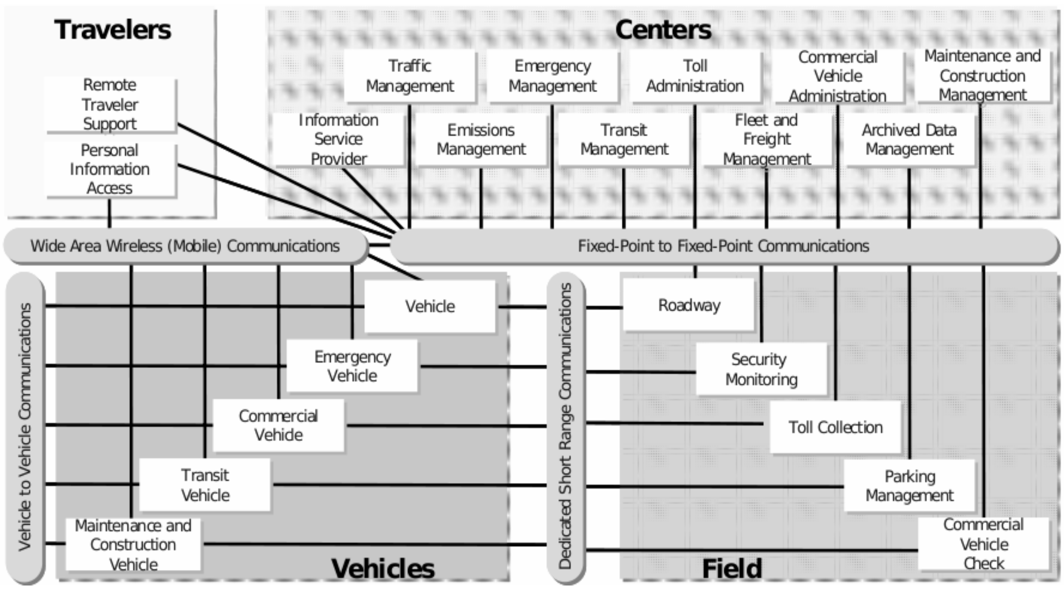

Figure 2. High-level architecture diagram

Table 1. Communication technologies

Communication Type	Fixed point-to-point	Wide area wireless	Dedicated short-range	Vehicle-to-vehicle
Technologies	– Leased or owned twisted wire pairs – Coaxial cable – Fiber optics – Terrestrial microwave links – Spread spectrum radio – Area radio network	– WiMAX (IEEE 802.16e) – MBWA / Mobile-Fi (IEEE 802.20) – WRAN (IEEE 802.22) – GPRS/UMTS – HC-SDMA – S-UMTS/IMT 2000 – Broadband Satellite Multimedia (BSM) – Geomobile Radio Interface (GMR)	– DSRC/WAVE – Infrared – Wi-fi (IEEE 802.11a/b/g/n etc.)	– DSRC/WAVE – Infrared – UWB (IEEE 802.15.3a)

4. IVC APPLICATIONS AND DEPLOYMENT

V2V and V2I main applications may be grouped in three categories (Luo 2004): information and warning functions, communication-based longitudinal control and cooperative assistance systems. The first category comprises the dissemination of road information to vehicles far away from the place problem occurred, such as road incidents, traffic congestion, surface condition, etc. The second category involves platooning capabilities to improve traffic efficiency and warnings about road accidents ahead. The last category refers to the cooperation between vehicles, such as cooperative adaptive cruise control (Arem 2006), automatic collision warnings, cooperation at highway entering, at intersections, etc. Some of the V2V/V2I applications, defined by the US Vehicle Safety Communications Consortium are presented in Table 2.

The development of vehicle communications is more active in Europe, USA, and Japan. In Europe, eSafety research program from EU Intelligent Car Initiative, and industry driven project Car2Car Communication Consortium are some of the lead actors; in US, the Vehicle-infrastructure Integration (VII) and the California Partners for Advanced Transit and Highways (PATH); in Japan, the Advanced Safety Vehicle (ASV) Program, where some testing has been conducted (Wani 2004). Among the ASV technologies, adaptive cruise control (ACC), lane keeping support system, automatic braking system for reducing injury, curve overshooting preventing support system and night time forward pedestrian advisory system are now on market, while stop-and-go system for following a preceding vehicle in congested traffic and emergency braking advisory system are at a driving test stage.

Table 2. V2V/V2I applications

V2V applications	V2I applications
– Approaching Emergency Vehicle Warning – Blind Spot Warning – Cooperative Adaptive Cruise Control – Cooperative Collision Warning – Cooperative Forward Collision Warning – Emergency Electronic Brake Lights – Highway Merge Assistant – Lane Change Warning – Post-Crash Warning – Pre-Crash Sensing – Vehicle-Based Road Condition Warning – Vehicle-to-Vehicle Road Feature Notification – Visibility Enhancer – Wrong Way Driver Warning	– Blind Merge Warning – Curve Speed Warning – Emergency Vehicle Signal Preemption – Highway/Rail Collision Warning – Intersection Collision Warning – In-Vehicle Amber Alert/Signage – Just-In-Time Repair Notification – Left Turn Assistant – Low Bridge Warning – Low Parking Structure Warning – Pedestrian Crossing Information at Intersection – Road Condition Warning – Safety Recall Notice – SOS Services – Stop Sign Movement Assistance – Stop Sign Violation Warning – Traffic Signal Violation Warning – Work Zone Warning

The period to implement IVC depends of many and diverse factors. Because life span of new vehicles is about 15 years, vehicles sold now will be rolling by 2022. This leads to a situation where some sort of add-on equipment should be developed, to allow installation in vehicles not prepared from initial manufacturing. Moreover, since new equipped vehicles are expected 3-5 years from now, the communication equipment should be stable enough to be operational by, say, 2028. Since the penetration required to initial effectiveness of IVC is about 1.5% to 6% (depending on traffic load) (Herrtwich n.d.), only 5 years after the initial deployment will the communication systems be of some use. Clearly, some imagination is required here to promote IVC in large scale.

In a vision of fifteen years from now presented by RITA (Architecture Development Team 2007b), short-range wireless communications will be widespread, allowing applications such as visual hazard warning signs, advisory messages, in-vehicle signing and probe information collection. Cooperation between vehicles will allow improvements in safety and in dynamic traffic management. Better incident and emergency management efficiency, using automatic call systems that will be standard equipment of most vehicles, will save thousands of lives. An emergency vehicle will receive priority and signal scheduling to ensure the fastest route to the local of the emergency. Vehicles will use automatic control on some freeways, increasing traffic throughput by reducing the space between vehicles. These features and many others may contribute to a safer, cleaner and more efficient transportation system.

5. IVC AND DRIVERS: SOME ISSUES

Nowadays there are thousands of deaths and severe injured people in the roads all over the planet. According to World Health Organization, in 2004 there were 1.2 million fatalities and over 50 million injured in traffic incidents. Vehicle manufacturers had covered a long way towards more secure vehicles but the numbers of accidents are still unacceptable high. Although many factors may contribute to that situation (human behavior, road condition, etc), every improvement in security is welcome. While some systems, namely Advanced Driver Assistance Systems (ADAS) aim to support driving task (cooperative collision warning, cooperative adaptive cruise control, lane change warning, etc), other communication systems (cellular phones, infotainment systems, Internet access and navigation systems) may compete with driving task. However, even the former may lead to driver’s distraction. According to a study from US National Highway Traffic Safety Administration (NHTSA) (Klauer et al. 2006), secondary tasks (e.g. adjusting, operating and looking at a device) account for 23 percent of all crashes and near-crashes. According to the same study, drivers engaging in visually and/or manually complex tasks have a three-time higher near-crash/crash risk than drivers who are attentive. Another study, realized by Crash Avoidance Metrics Partnership (CAMP), in collaboration with US government, concluded that visual-manual tasks had a more pronounced effect of driving performance than the auditory-vocal tasks (Angell et al. 2006). A study about crash warning systems interfaces and human factors (Campbell et al. 2007) suggests some design guidelines concerning the use of a one-, two- or multi-stage warning systems, the prioritization of the warning messages, the presentation methods of the warning messages (visual, auditory, haptic), the warning timings, the adaptation between each type of warning system to each hazard situation, etc. The characteristics of the driver should also be taken into account when choosing the way he/she receives the messages.

6. CONCLUSIONS AND FUTURE WORK

Communications enabled vehicles are becoming a reality and the respective standards are close to a stable definition. If it is clear to all that communications should increase safety, it may not be the case if care is not taken to the system transmission’s final link of crucial safety messages: communication between the vehicle and the driver. Timing issues, distraction factors, single- or multi-stage warning systems, characteristics of the driver, are some of the several variables deserving research. To ensure all the communication steps are useful, the human-machine interface must be as efficient as possible. To study the efficiency of the solutions, it is important to develop models representing human behavior. Computer simulations that take into account traffic and communication issues should implement those models to allow adequate research results. Although traffic simulators take into account driver behavior, network simulators do not. Future work will be held on modeling and simulating human responses to several ways of message presentation to different type of drivers, in a more global traffic and communication system involving drivers and vehicles communicating with each other and with infrastructure, in an on-line mode of operation.

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