ISSUES AND RECENT TRENDS IN VEHICLE SAFETY COMMUNICATION SYSTEMS

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This paper surveys the research on the applications of inter-vehicle communications, the issues of the deployment and technology, and the current status of inter-vehicle communications projects in Europe, the United States and Japan. The inter-vehicle communications, defined here as communications between on-board ITS computers, improve road traffic safety and efficiency by expanding the horizon of the drivers and on-board sensors. One of the earliest studies on inter-vehicle communications began in Japan in the early 1980s. The inter-vehicle communications play an essential role in automated platooning and cooperative driving systems developed since the 1990's by enabling vehicles to obtain data that would be difficult or impossible to measure with on-board sensors. During these years, interest in applications for inter-vehicle communications increased in the EU, the US and Japan, resulting in many national vehicle safety communications projects such as CarTALK2000 in the EU and VSCC in the US. The technological issues include protocol and communications media. Experiments employ various kinds of protocols and typically use infrared, microwave or millimeter wave media. The situation is ready for standardization. The deployment strategy is another issue. To be feasible, deployment should begin with multiple rather than single services that would work even at a low penetration rate of the communication equipment. In addition, non-technological, legal and institutional issues remained unsolved. Although inter-vehicle communications involve many issues, such applications should be promoted because they will lead to safer and more efficient automobile traffic.

Key Words: ITS (Intelligent Transport Systems), Inter-vehicle communications, AVCSS (Advanced Vehicle Control and Safety Systems), Driver assistance systems, Automated driving systems

1. INTRODUCTION

The Intelligent Transport Systems (ITS) attempt to provide a solution to the twentieth-century's negative legacy of traffic accidents and congestion. Large-scale national ITS projects began in Europe, the US and Japan in the mid-1980s but, compared to those early years, recent ITS efforts have seen a markedly greater focus on safety. The EU's eSafety initiative[1], announced in November 2002, aims to halve the number of annual traffic accident fatalities in the EU by 2010. The United States' ITS Ten-Year Plan[2], announced in January 2002, talks about achieving a 15% reduction in the number of annual traffic fatalities by 2011, while the National Intelligent Vehicle Initiative (NIVI) Meeting in June 2003 announced a goal of reducing the rate of traffic accident fatalities from the then-current 1.51 deaths per 100 million vehicle-miles traveled (VMT) to 1 death per 100 million VMT by 2007. Against this background of ITS activities, vehicle safety communication systems based on inter-vehicle communications have been a topic of great interest around the world in recent years. Taking up this subject, this paper addresses inter-vehicle communications technologies, the history of systems for the applications, and current trends, and some issues for the future. The term of "inter-vehicle communications" can be also expressed as "vehicle to vehicle communications" or "car to car communications," and "inter-vehicle communications" is used in this paper.

2. ITS AND INTER-VEHICLE COMMUNICATIONS

2.1 The position of inter-vehicle communications within ITS

Under the ITS system architecture of the US and Japan[3], as indicated in Figure 1, ITS communications systems are defined to include four types of communications systems: inter-vehicle (vehicle to vehicle), road-to-vehicle, wide-area wireless and wireline. As this makes evident, the inter-vehicle communications are an important element of the ITS field. By definition, inter-vehicle communications include communications between drivers and between vehicles, but we will define it as communications between on-board computers. Systems introduced in this paper are accordingly those based on the definition.

One characteristic of inter-vehicle communications is that unlike road-to-vehicle communications, where the communications site is determined by the location of road

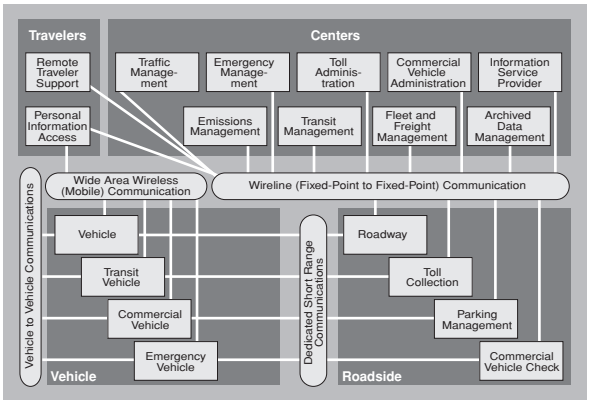

Fig. 1 Communication systems in ITS system architecture

beacons, communications with other vehicles can take place anywhere. Consequently, information and data that would be difficult or impossible to measure from a single vehicle can be collected through inter-vehicle communications. Inter-vehicle communications make it possible to expand the horizon of on-board sensing systems, a characteristic exploited in vehicle safety communication systems.

2.2 The history of research into inter-vehicle communications

Probably the earliest research into inter-vehicle communications was conducted in the early 1980s at the Association of Electronic Technology for Automobile Traffic and Driving (now the Japan Automobile Research Institute). This research treated inter-vehicle communications primarily as traffic and driver information systems incorporated in ATMS/ATIS (Advanced Traffic Management Systems/ Advanced Traveler Information Systems). Efforts have since been made to apply it to driver assistance and automated driving systems incorporated in AVCSS (Advanced Vehicle Control and Safety Systems). From the 1990s through 2000, automated platooning systems such as California's PATH (Partners for Advanced Transit and Highways)[4] and the EU's Chauffeur[5], as well as cooperative driving systems in Japan[6-8], made automated vehicle platooning a reality through the transmission of data, such as each vehicle's acceleration, through the inter-vehicle communications that would be impossible to measure from other vehicles. Recently, as described above, systems for improving automobile traffic safety that use inter-vehicle or road-to-vehicle communications to relay incident or emergency information from a preceding vehicle to succeeding vehicles[9,10] have generated a great deal of interest in Europe, the US and Japan.

3. APPLIED SYSTEMS INCORPORATING INTER-VEHICLE COMMUNICATIONS

Broadly speaking, inter-vehicle communications are applied to traffic and driver information systems within ATMS/ATIS (Advanced Traffic Management Systems/ Advanced Traveler Information Systems) or to driver assistance and automated driving systems within AVCSS (Advanced Vehicle Control and Safety Systems). In general, inter-vehicle communications in ATMS/ATIS applications are ad hoc and sporadic. This is also usually the case with many driver assistance applications in AVCSS. For automated driving systems such as automated platooning inter-vehicle communications must be maintained with a short period. Major research to date and its distinctive characteristics will be introduced below. Note that ATMS, ATIS and AVCSS are technical terms defined by ITS America[11] and represent the mainstream ITS systems.

3.1 ATMS/ATIS applications

Around 2000, a system for incident warnings was developed by the Ohio State University using 220MHz VHF[10], whose range of 1 to 2 kilometers made the inter-vehicle communications possible even where the penetration rate of the communication equipment is low. The researchers were interested in inter-vehicle communications because of the difficulty of preparing infrastructure intelligence to serve such a vast country.

Also around 2000, a German consortium proposed a system for relaying accident and incident information over inter-vehicle communications using the same 800MHz frequency band to that used for car phones[9]. The idea was that sending accident or incident information to succeeding vehicles would prevent multiple-vehicle accidents, particularly on suburban roads under poor visibility conditions. Accidents or incidents would be detected automatically based on the use of hazard lights, vehicle acceleration, airbag deployment or signals from the anti-lock braking system (ABS) and sent, together with GPS (Global Positioning System) location data from the navigation system, to be sorted out on the receiving end.

3.2 AVCSS applications

In the United State, Demo97, a large-scale demonstration of an automated driving system, was held in San Diego in 1997. The California PATH team[4] participating the Demo had a platoon of 8 passenger vehicles demonstrating automated driving at a speed of 96km/h and a gap distance of 6.3m, as illustrated in Figure 2. This sys-