THE EVOLUTION OF ONBOARD VEHICLE SAFETY COMMUNICATIONS AND DRIVER ASSISTANCE SYSTEMS

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1. INTRODUCTION

As we move further into the 21^{st} century, we look expectantly ahead to a new generation of vehicles in which advanced sensors and communications abilities will drastically improve vehicle safety, reliability, and comfort. The more sensors a vehicle has, and the more advanced those sensors become, the better the picture they paint of the driving environment. The development of advanced sensors has been a key contributor to the evolution of current driver assistance systems (e.g., anti-lock braking systems (ABS), adaptive cruise control (ACC), electronic stability programs (ESP), etc.), and will continue to play a crucial role as the next generation of driver assistance systems comes into being.

While improved sensor technology has helped spur the evolution of driver assistance systems to date, wireless vehicle communications will be part of future efforts to improve vehicle safety and driver assistance systems. Wireless communications enable the collection of readings from the sensors of a large number of vehicles. This data can then be used to provide a broader near-real-time picture of the driving environment to help driver assistance systems perform better.

Around the globe, government and industry are working to advance wireless-enabled safety communications.

The U.S. is focused on the Vehicle Infrastructure Integration (VII) program, a follow-up to the U.S. Department of Transportation's (U.S. DOT) Intelligent Vehicle Initiative (IVI). The IVI program, concluded in 2005, undertook to reduce the number and severity of crashes through driver assistance systems, both vehicle and infrastructure-based. In its final report, the IVI identified three challenging areas of traffic safety and management: intersection collision avoidance, vehicle safety system integration, and vehicle-infrastructure cooperation. U.S. DOT undertook the Vehicle Infrastructure Integration effort to address these challenges.

The VII initiative seeks to establish a two-way data conversation between the land-based systems and vehicles on the road. The purpose of this connection is to improve the safety and efficiency of the U.S. transportation system. Participants include members of the automotive, electronics, and communications industries along with federal and state partners. This public-private cooperation aims to develop and deploy a cost-effective national intelligent transportation system. A number of other initiatives, mostly spearheaded directly by industry, are working toward the same goal.

The European Commission is promoting a similar approach through the Cooperative Vehicle-Infrastructure Systems (CVIS) and SafeSpot projects. The automotive industry plans to use this technology to increase the efficiency and safety of road travel while also developing new commercial vehicle-oriented information services. European vehicle manufacturers are working to establish a European standard for wireless vehicle-to-vehicle communications through their Car-2-Car Consortium.

In Japan, the Advanced Cruise-Assist Highway System Research Association (AHSRA) project has pioneered the exploration of vehicle-infrastructure communications. The Japanese government is now pursuing the initial rollout of an infrastructure communications capability for vehicle safety warnings.

2. DRIVER ASSISTANCE SYSTEMS

Since wireless-enabled information from outside the vehicle is not yet generally available, present day driver assistance systems are self-contained in the vehicle. These systems continue to grow in sophistication and capability.

An illustration of this is cruise control, which allows the driver to select a set speed that the vehicle maintains until the driver intervenes. Basic cruise control is now being enhanced by the introduction of proximity sensors. In some high-end vehicles, adaptive cruise control (ACC) uses the data from these sensors to maintain at least a set distance from the vehicle in front by adjusting the vehicle’s speed below the preset speed when necessary.

Anti-lock brake systems (ABS) help to balance wheel spin and prevent wheels from locking in slippery road conditions. With the help of wheel sensors, ABS can brake individual wheels as necessary to prevent skidding, a capability which is unavailable directly to the driver. A spin-off of ABS is electronic stability control (ESC) that is sufficiently good at preventing rollovers due to sideways skids that it is being made mandatory equipment in many parts of the world.

Both ACC and ABS provide good examples of how driver assistance systems have evolved to improve the safety of vehicle occupants by detecting potentially hazardous conditions, warning the vehicle operator of adverse conditions and, when necessary, taking partial control of vehicle functions. For the future, it is clear that crash prevention will be the main concern for the development of new advanced driver assistance systems.

2.1. Vehicle Sensors

As new sensor technology becomes available, vehicles are better able to interpret their immediate surroundings to support driver assistance systems. Relatively new sensor technology includes such advanced systems as: blind spot detection, video detection and image processing systems, and closing velocity sensors. As vehicle sensors evolve and expand, self-contained driver assistance systems will also continue to evolve, offering even higher levels of safety.

For example, a highly accurate, up to date geographic map database is a very useful additional sensor to help the camera and image processing system do a better job of lane keeping, and to help the ACC function determine if a vehicle, apparently in front is actually in the same lane.

However, even advanced sensors on a single vehicle cannot create as accurate a picture of the driving environment as the data aggregated from a wide range of sources, including the sensor readings from vehicles that previously traveled the road segment. In the future, wireless communications will gather sensor readings from multiple sources, validate and aggregate them, and to deliver them to vehicle safety systems to further improve the safety of the world's roads.

In developed countries, this will occur within 10 years. It will be harder and later in less developed countries.

3. VEHICLE COMMUNICATIONS

Historically, vehicle communications has been a one-way conversation, mostly consisting of "what can we say TO the vehicle." For example, the venerable European Radio Data System (RDS) sends traffic and other basic information to vehicles, but does not gather data from the vehicle. Two-way conversations have mostly been restricted to relatively simple applications like electronic toll collection.

However, the opportunities for two-way conversations between vehicles and land-based systems are now beginning to expand. Dedicated short-range communications (DSRC) is already being used for electronic toll collection worldwide and for checking commercial vehicle credentials in the U.S. In the U.S., the Federal Communications Commission has allocated 75 MHz of bandwidth in the 5.9 GHz band for DSRC to advance safety. This specific type of DSRC is called WAVE (Wireless Access for the Vehicular Environment). WAVE is the focus of communications for the U.S. DOT's VII program. In addition, there are many other communications technologies that the industry is actively exploring to establish other avenues for linking vehicles with land-based systems.

3.1. Communications Technologies

No one communications technology is suitable for all vehicle communications at all times and places. While the VII program has adopted WAVE as the initial communications technology for a national intelligent transportation system, other technologies are also currently available or becoming available in the near future.

For example, WAVE has very low latency and a very high data rate, but it is available in small footprints of about 300 meters around roadside or overhead beacons. This works well for electronic toll collection and for other applications where waiting to arrive at the footprint is not a problem. However, it is less serviceable for applications like automatic crash notification (ACN) which may need to send an emergency message outside of that footprint. In addition, WAVE is mainly aimed for deployment along major highways and in urban centers; it probably cannot provide universal coverage in rural areas

Another currently available wireless technology is cellular technology. Cellular technology already provides a high level of coverage for urban areas and highways. However, the cost of transmitting data using cellular technology is high and coverage is spotty in many rural areas.

Mobile wireless broadband also appears poised to be a major technology for vehicle data communications. Technologies like mobile WiMAX (standardized as IEEE 802.16e) are in the early stages of widespread testing. If the tests are successful, deployment is expected to occur rapidly. Again, the economics favor initial and primary deployment in urban areas and along major highways.

There are ways to address vehicle connectivity in rural areas. The FCC has set aside the 700 MHz band for use by public safety services in the U.S. It may be possible to make the 700 MHz band available for vehicle safety communications in rural areas where the public safety demands on this band will be relatively low. In addition, multiple antenna signal processing (MAS) technology can help mobile wireless broadband economically provide greater coverage, including in more remote areas.

To ensure connectivity for safety, vehicles will need to be able to use multiple communications technologies, selecting the technology which is most readily and economically available wherever the vehicle is operating.

3.1.1. Multiple Means of Communication

The development of standards to facilitate vehicle use of a wide range of communications technologies is the work of the Wide Area Communications Working Group (WG16) of the international standards committee on ITS (ISO/TC204). Currently, WG16 is developing CALM (Communications Air Interface, Long and Medium Range), a set of umbrella protocols to facilitate the transparent in-vehicle use of a variety of communications technologies. CALM currently encompasses 2.5G and 3G cellular, satellite, infrared, millimeter wave (63 GHz), DSRC/WAVE at 5.x GHz, and wireless mobile broadband technologies.

3.2. Probe Processing

It has already been noted that safety systems will work best if they have access to sensor data from many vehicles. Probe processing is the process of gathering and merging the sensor readings from many vehicles in combination with information from other sources (infrastructure-based sensors, police reports, weather reports, construction plans, etc.) to produce a clear understanding of the overall driving environment.

Probe data enhances the operation of advanced driver assistance systems by advising vehicles in an area of adverse conditions such as obstacles, crashes, or hazardous pavement conditions.

Probe processing is also the most promising mechanism for building the super-accurate road map databases needed to support in-vehicle safety applications.

3.3. Centralized Data Utility

New communications technologies applicable to vehicle safety and telematics will continue to appear. Over time, vehicles' use of communications will expand in new directions and grow increasingly sophisticated. One interesting consequence of this is that, at any particular time, the vehicles on the road will collectively have widely differing levels of communications sophistication. This will also be true of the land-based systems that need to interact with vehicle systems. For example, technology available at public safety answering points

(PSAPs) – the targets of ACN data messages – will vary widely over time and from one locale to another.

It is going to be very difficult for the PSAPs (and other land-based systems) to keep up with all of the communications variations and innovations that will arise every year in new vehicles. One approach would be to constrain all future vehicle communications to the relatively low level of sophistication that will be present now or in the near future, but the disadvantages of this approach are large and obvious.

A more promising approach is to create a centralized data utility, potentially on behalf of the vehicle manufacturers collectively. Such a utility would be able to accept any data message that any operational vehicle was capable of sending, and to send data to its intended recipient in the form that it wants and is capable of handling. This would be true both for land-based operations like ACNs and for messages directed back to vehicles.

This approach allows vehicle manufacturers to continue to expand the sophistication of their vehicles' communications capabilities and relieves land-based systems from individually having to keep up with all of the changes.

4. CONCLUSION

As vehicles become able to sense ever more information about their surroundings, it is important that the issue of safety features prominently in decisions as to what direction intelligent transportation will take. For there to be the type of universal connectivity discussed in this paper, industry and government must work closely together for the benefit of all involved.