THE STATUS OF VEHICLE-TO-VEHICLE COMMUNICATION AS A MEANS OF IMPROVING CRASH PREVENTION PERFORMANCE.

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ABSTRACT
This paper provides the status of NHTSA sponsored research on vehicle-to-vehicle and vehicle-to-roadside communications as a means of improving crash prevention performance. A description of Dedicated Short Range Communications (DSRC), the leading wireless technology for vehicle-to-vehicle and vehicle-to-roadside communications is presented. Next a discussion of standards development, including the actions of the Federal Communications Commission (FCC) to allocate spectrum, the American Society of Testing and Materials (ASTM) and Institute of Electrical and Electronic Engineers (IEEE) to develop standards, and the Society of Automotive Engineers (SAE) common vehicle-to-vehicle safety message set efforts, are given. Potential vehicle safety applications including intersection crash warning and emergency electronic brake lights are discussed. Discussed next are crash prevention benefits. Finally, message security is covered.

INTRODUCTION
Wireless technologies are rapidly evolving. Dedicated Short Range Communications (DSRC) is one of these wireless technologies. At 5.9 GHz DSRC offers the potential to support short to medium range, very high data rate, wireless communications between vehicles, and between vehicles and the roadside.

It is envisioned that vehicle-based crash prevention performance can be enhanced by information that could be wirelessly transmitted to vehicles from the roadside and from other vehicles.

The United States Department of Transportation (USDOT) has worked with the Collision Avoidance Metrics Partnership (CAMP) to do pre-competitive safety research jointly with the Automotive Original Equipment Manufacturers (OEMs).

The Vehicle Safety Communications Consortium (VSCC) of CAMP, which consists of seven OEMs: BMW, DaimlerChrysler, Ford, GM, Nissan, Toyota, and Volkswagen was formed to investigate the potential of using vehicle-to-vehicle and vehicle-to-roadside communications as a means of improving crash prevention performance.

The 3-year VSC project was established in 2002 to do four things: 1) estimate the potential opportunity for safety benefits of communication-based vehicle safety applications and define their communications requirements; 2) ensure that proposed DSRC communications protocols and standards meet the needs of vehicle safety applications; 3) investigate specific technical issues that may affect the ability of DSRC to support deployment of vehicle safety applications; and, 4) estimate the deployment feasibility of communications-based vehicle safety applications[i]. Along these lines the automotive team identified and evaluated a comprehensive list of vehicle safety applications enhanced or enabled by external communications, determined their respective communications requirements, and worked with standards development organizations to ensure that proposed 5.9 GHz Dedicated Short Range Communications (DSRC) protocols support vehicle safety applications.

Driver assistance systems are currently being developed and deployed as the result of improvements in critical sensing technologies such as radar. The VSC project introduces the added technical dimension of wireless technology to the potential development of driver assistance systems. The addition of wireless communications enables a number of vehicle safety applications.

DSRC OVERVIEW
In its most basic form, DSRC consists of a pair of transceivers: the vehicle mounted radio known as the Onboard Unit (OBU) and the Road Side Unit (RSU). The RSU is normally fixed along the roadside – like a road sign or traffic signal. Communications between the two units may be bi-directional or broadcast and are isolated to relatively small communication zones.

The radios will be built to conform to the DSRC Standard, IEEE 802.11p. The standard is based on IEEE 802.11a which is one of the standards already being used for laptop computers to access wireless Local Area Networks (LANs). The 802.11p Standard has been optimized to work in the vehicle environment.

Requirements include the ability to communicate quickly, be interoperable across all of North America, operate in all weather conditions, operate with a large number (50-100) of units within the communication zone, and be low cost to name a few.

In addition, early work has shown that vehicle safety applications require very low message latencies. Urgent vehicle safety messages carrying critical information need to be delivered in ~100 milliseconds. This requirement requires an uncluttered communications channel. Initial design and testing has shown that DSRC technology is capable of very low latency communications, less than ~100 milliseconds should be possible. Other wireless communications technologies, such as cellular telephones, do not appear to be able to achieve this low latency requirement. DSRC also offers the capability of transmitting broadcast and uni-cast messages.

The data rate is from 6 – 27 Mbps. Transmission power is adjustable up to a limit of 28.8 dBm and transmission range can extend to almost 1,000m.

STANDARDS DEVELOPMENT

In their report and order (R&O), published in the Federal Register in August 2004, the United States Federal Communications Commission (FCC) set aside 75 MHZ of Radio Spectrum at 5.9 GHz for DSRC. This spectrum is available for public safety and private applications and requires licensing. The rule specifies the lowest layer (of the Open Systems Interconnection (OSI) Computer Network Architecture[1]) standards (i.e. ASTM E2213-03[2]). This standard specifies seven 10-MHz wide channels that include a dedicated Control channel for announcements and warnings, a high-availability, low-latency channel, and multiple service channels.

The Control channel is used to manage all devices in the ad-hoc network. The use of this channel is restricted so it will not be overloaded. Overloading could degrade system performance.

Life-threatening vehicle safety messages will receive the highest priority in a 1-8 priority scheme[ii]. This allows them to be transmitted with the least amount of delay.

The Society of Automotive Engineers (SAE) drafted a common vehicle-to-vehicle safety message set. This message set is being put into the standard format and is being forwarded through the process to become an official SAE standard. A common message set for vehicle-to-roadside messages is also under development[iii].

The FCC R&O does not specify any standard for use for the upper layers of the OSI model. Work continues on standardizing specifications for these upper layers. This ongoing work will require testing, validation, and will likely result in revisions to the draft standards.

POTENTIAL APPLICATIONS

As a first step within the VSC project, almost 100 potential automotive safety application scenarios were identified and ranked. These ranged from Adaptive Drivetrain Management to Wrong-way Driver Warnings. The next step involved developing preliminary communications requirements for the highest priority application scenarios. Based upon these preliminary requirements, an analysis of alternative wireless technologies was completed. DSRC was the clear choice for the vehicle safety applications scenarios identified.

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[1] OSI is a standard description or "reference model" for how messages should be transmitted between any two points in a telecommunication network. Its purpose is to guide product implementors so that their products will consistently work with other products. The reference model defines seven layers of functions that take place at each end of a communication path: 1 physical (communications medium), 2 data link, 3 network, 4 transport, 5 session, 6 presentation, 7 user's application.

[2] Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems – 5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

Each vehicle safety application scenario, such as Emergency Electronic Brake Lights or Traffic Signal Violation Warning, was further defined during additional research, and a preliminary estimate of safety benefits was derived. The basis for this estimate was the "44 Crashes[3]."

CRASH PREVENTION BENEFITS

To estimate safety benefits the VSC team compared and rated the application scenarios. To determine the estimated number of vehicles equipped with each application scenario in each year after being introduced in the commercial market the OEMs provided market penetration estimates. These estimated allowed each application to be put into one of three time frames: Near-term systems were considered deployable between the years 2007 to 2011, mid-term between 2012 to 2016, and long-term beyond 2016.

From the rankings determined above the team selected a subset of safety applications based on: 1) the estimated safety benefits and 2) the selection adequately covered the range of safety applications. A measure of Functional Years Lost[4] was used to rank the near-term, mid-term, and long-term applications[iv].

Based on the analysis, eight applications were chosen as representative of the vehicle safety applications from the standpoint of determining communications requirements:

Near-term:

1. Traffic Signal Violation Warning
2. Curve Speed Warning
3. Emergency Electronic Brake Lights

Mid-term:

4. Pre-Crash Warning
5. Cooperative Forward Collision Warning
6. Left Turn Assistant
7. Lane Change Warning
8. Stop Sign Movement Assistance.

[3] General Motors (1997). 44 crashes, v.3.0 Warren, MI: NAO Engineering, Safety & Restraints Center, Crash Avoidance Department.

[4] Functional Years Lost is a non-monetary measure that sums the years of life lost to fatal injury and the years of functional capacity lost to nonfatal injury.

Detailed communications requirements were developed from analysis of these applications. These requirements state the need for small (< ~500 bytes) broadcast messages with low latency.

SECURITY

As part of their work, the VSC addressed security concerns for vehicle safety applications. Other organizations are addressing security concerns for non-vehicle safety applications such as public safety applications and commercial (Toll) applications.

Security is a key concern in any safety-critical application[v]. The general security requirement for broadcast-based safety communications includes the need to make sure the transmission comes from a trusted source (and has not been tampered with). This is known as message authentication or origin integrity and is the recommended approach for securing DSRC messages.

In order to develop a robust security architecture and protocol, a threat assessment for the various vehicle safety applications was performed.

From the threat assessment, a security architecture and protocol was developed. This architecture and protocol is currently undergoing testing and review at the National Institutes of Standards and Technology (NIST). The testing will likely determine an appropriate level of security overhead (encryption effort, bits per word, etc). The amount of overhead will need to be balanced between impact on throughput and latency and the appropriate level of security needed for vehicle safety applications.

The output from this security work will help guide the standards development process.

SUMMARY

This paper provided the status of NHTSA research on vehicle-to-vehicle and vehicle-to-roadside communications as a means of improving crash prevention performance. A description of Dedicated Short Range Communications DSRC, the choice for vehicle safety applications, was presented. Next, a discussion of standards development, to include the actions of the FCC to allocate 75 MHz of Radio spectrum at 5.9 GHz, the ASTM and IEEE on the development of standards for the upper layers of the OSI model, and the development of a common vehicle safety message set lead by the SAE was given. Potential vehicle safety applications to include intersection crash warning and emergency electronic brake lights were discussed. Based on the estimated safety benefits, the team chose eight applications to represent the vehicle safety applications envisioned. The eight were used to develop detailed communications requirements. Finally, the need for message authentication was presented.

DSRC appears to be an important enabler of a number of vehicle safety applications.

ACKNOWLEDGEMENTS

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PROGRAM INFORMATION

Copies of the CAMP VSC Final Technical report will be available in printed and electronic form from NHTSA (http://www.nhtsa.dot.gov) in mid 2005.

REFERENCES

1 Vehicle Safety Communications Project, Task 3: Identify Intelligent Vehicle Safety Applications Enabled by DSRC – Interim report, CAMP January 30, 2003.

2 Conversations with Tom Schaffnit, Schaffnit Consulting

3 Conversations with Steve Tengler, Senior Project Engineer ITS Strategic Planning, Nissan

4 T. Miller, J. Viner, S. Rossman, N. Pindus, W. Gellert, J. Douglass, A. Dillingham, and G. Blomquist, "*The Costs of Highway Crashes*". FHWA-RD-91-055, October 1991.

5 Conversations with Eric Rescorla, senior engineer, RTFM