TECHNICAL REPORT: CVEL-07-003

A REVIEW OF VEHICLE-TO-VEHICLE AND VEHICLE-TO-INFRASTRUCTURE INITIATIVES

Caitlin Motsinger[1] and Todd Hubing[2]

[1]University of Notre Dame
[2]Clemson University

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EXECUTIVE SUMMARY

This document describes the current (2007) technological environment in vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. More specifically, it identifies various opportunities for "smart tires" equipped with built in electronic systems. These can take two forms. First are onboard sensors to provide information on roadway conditions, which can then be passed on to both the driver and other vehicles for advanced safety applications. Secondly, the actual hardware for the V2V and V2I transmissions can be placed in the tire or wheel assembly. The additional degree of freedom in the motion of tires makes them a good location for V2V and V2I antennas. The report is broken into three subparts, the first two addressing these two applications for tire electronics, and the third providing pertinent economic background information.

Introduction

As the number of cars on the road increases, so do the dangers and economic costs from automobile accidents. In the past, safety systems have focused on reducing driver injury in case of an emergency. Thus the introduction of seat belts, air bags, and more recently products like OnStar, which can automatically contact emergency services and help locate the scene of an accident.

The current trend in safety is not just to mitigate the effects of automobile accidents, but to prevent their occurrence all together. This involves making vehicles and roadways "smarter" through advanced electronics. Technology in this area is often collectively referred to as ITS, Intelligent Transportation Systems. The hope is that these new safety systems will be able to warn drivers of dangerous situations in time to take preventative action.

Two areas of active ITS research are advanced sensor technology and inter-vehicle communications. With better sensors and data communication techniques, a driver can be more aware of his or her environment. This allows the driver to react appropriately to situations such as slippery roads and poor visibility. Add vehicle-to-vehicle communications, and drivers can share this information with each other, providing warnings before danger is imminent. Drivers can also be made more conscious of each other's location, so as to avoid intersection collisions and lane changing accidents.

Vehicle-to-infrastructure communications are a venue for traffic management personnel to supply real-time updates on weather conditions and accident locations. In addition to safety related information, V2I communications provide drivers information that allows them to change their proposed route or departure time to avoid heavy traffic.

This document provides basic background information on various research initiatives in advanced sensors, V2V, and V2I communications. It was written with the intent of identifying areas where smart tire electronics could play a developmental role.

Major Involved Organizations

American Society for Testing and Materials (ASTM)

ASTM is a voluntary international standards organization, and is the primary organization responsible for developing the layer protocols for Designated Short Range Communications (DSRC).

Car2Car Communication Consortium

Car2Car is comprised of European automakers and automotive parts suppliers. This umbrella committee seeks to bring together the standards and technology being developed for vehicle-to-vehicle communication by various independent projects in Europe, as well as monitor developments in North America. Specifically, the organization seeks to establish standards for wireless LANs, and promote the allocation of frequencies for vehicle communications.

Crash Avoidance Metrics Partnership (CAMP)

The CAMP research organization was originally formed in 1995 by Ford and GM. It now also includes BMW, DaimlerChrysler, Navigation Technologies, Nissan, Toyota and Volkswagen. The purpose of the program is to investigate and accelerate the implementation of new technology on passenger vehicles to avoid automobile accidents (Shulman & Deering, 2003).

European Commission

The European Commission is the executive body of the European Union. It is comprised of a president and 26 commissioners appointed by the member states.

Institute of Electrical and Electronics Engineers (IEEE)

IEEE is a professional society that seeks technological advancements in the electrical engineering field. It is in charge of defining and publishing many standards that guide wireless protocols.

International Organization for Standardization (ISO)

The ISO is the world's largest creator of technical standards. It is a key player in European standards development.

National Highway Traffic Safety Administration (NHTSA)

The NHTSA is a U.S. government organization that sponsors research, public awareness, and law-making to promote vehicle safety.

Society of Automotive Engineers (SAE)

SAE is a professional society of business and engineering personnel involved in mobile systems. It is also responsible for creating and maintaining various technical standards.

Part I: Opportunities for Advanced Tire-Sensor Technology

This portion of the report focuses on initiatives that are specifically tailored to advanced sensor development for V2V and V2I applications. The projects listed here are all part of the eSafety project, which is one of 3 pillars of the EU Intelligent Car Initiative that has set the goal of cutting traffic fatalities in half by 2010. The program is sponsored by the European Commission's Department of Information Society and Media.

FRICTI@N

The objective of the FRICTI@N project is to combine information from vehicle-dynamics, environmental, and tire sensors to create an onboard system to predict fiction conditions and road slipperiness. The goal is not to create new sensors, but to change how the data from current sensors are used and integrated. Data is fed to a "FRICTI@N-Estimation-Observer" to estimate the tire-road friction using on-line mathematical methods (Fricti@n: Project Objective, 2007). Systems such as slip control, emergency braking, electronic stability, adaptive cruise control and roll-over avoidance could all benefit from friction information. The project is slated to run for 36 months, from January of 2006 to December of 2008 (Friction: Fact Sheet, 2006).

Enhanced Floating Car Data (EFCD)

Global System Telematics (GST) is funded by the EU as an "integrated project [to create] an open and standardized end-to-end architecture for automotive telematics services" (GST, 2007). The group is actually managed by representatives from the automotive industry, with the head Steering Committee comprised of Renault (Chairman), BMW (Vice-chairman), Bosch, DaimlerChrysler, Deutsche Telekom/T-Systems, ERTICO, Fiat, Ford, France Télécom/Orange, Mondial Assistance/Allianz, Motorola, Opel, Siemens VDO, SRA, Telecom Italia and Volvo.

GST has seven-sub projects aimed at developing safety telematics in Europe. One of these, Enhanced Floating Car Data (EFDC) developed technology to equip cars with mobile sensors that relay information back to the central bus and then out to a collection infrastructure. The hope for this project is that a better data structure will result in improved event detection, and a message control system will optimize communication behavior.

The system will be able to support different methods of communication: Radio Data System-Traffic Message Channel (RDS/TCM), Digital Audio Broadcasting (DAB), Dedicated Short Range Communications (DSRC), etc. (GST, 2007). RDS-TMC is an FM or satellite broadcast of traffic information that can be used by navigation units, and is found in many European countries. DSRC is described in greater detail later in this document. Ford had the responsibility of developing the data collection methods. The technology is OSGi based to make it open to additional hardware and remote software updates (Burkert, 2006).

The GST benchmark is to have all new vehicles comply with the EFCD standard by 2012, and reach a critical density of equipped vehicles in Europe by 2020 (GST EFCD, 2007). EFCD ran from March 2004 to March 2007.

PReVENT (ProFusion)

PReVENT research seeks to reduce the number of accidents through active safety systems. One of its subprojects, ProFusion, is working to create a modular architecture for sensor data. The goal is to deliver "an extended view of the vehicle environment to applications. Data structures are defined at each processing step during the fusion process going from raw sensor data to signal features and objects detected in the environment" (ProFusion2, 2004). Prevent is slated to run until January 2008 (PReVENT: Factsheet, 2004)

TRACKSS

TRACKSS (Technologies for Road Advanced Cooperative Knowledge Sharing Sensors) is a project for "developing new systems for cooperative sensing and predicting flow, infrastructure and environmental conditions surrounding traffic" (Project Objectives, 2006). This involves developing new sensing technologies for both vehicle and infrastructure, allowing for easy sensor integration in the overall architecture, and providing ways to share and process data to yield useful information about the vehicle's driving environment. The project has an end date of June 2008 (TRACKSS, 2006).

Part II: Opportunities in Vehicle-to-Vehicle/Infrastructure Communication Systems

North American Government Initiatives

There are currently many initiatives across the globe in V2V and V2I communications. Though performed by different groups with different objectives, the overall goal is the same: to provide drivers with real-time information beyond what is available through the senses alone. This allows for better decision making, which enhances safety and driving efficiency. It is worth noting that while the projects below are listed under communications, many of them could also yield opportunities for advanced-tire sensors.

Vehicle Safety Communications Project (VSC)

The primary goal of VSC was to define "use cases;" the most beneficial preventative measures against traffic accidents. High priority use cases include: traffic signal violation warning, curve speed warning, emergency electronic brake light, pre-crash sensing cooperative collision mitigation, cooperative forward collision warning (FCW), left turn assistant, lane change warning, and stop sign movement assist.

The VCS Project also tested communications under difficult performance conditions, and determined that wireless communication was possible even with relative speeds of 225 kmh. (Kellum & Deegener, 2007). Research was done by the Crash Avoidance Metrics Partnership (CAMP).

Cooperative Intersection Collision Avoidance System (CICAS)

This initiative sponsors three main areas of work: CICAS-Violation (CICAS-V) for major intersections, CICAS-Stop Sign Assist (CICAS-SSA) for minor intersections, and CICAS-Signalized Left Turn Assist (CICAS-LTA). All three strive to avoid collisions by warning drivers of imminent intersection violations. CICAS-V has been developed the furthest, with prototype testing to begin in California, Michigan, and Virginia in 2007. The other projects are still in the initial concept phase. CICAS is testing the use of DSRC for V2R applications, with an initial system being tested in Michigan (CICAS: Current Activities, 2007).

Vehicle Infrastructure Integration (VII)

The VII initiative is a push for both vehicle-to-vehicle and vehicle-to-road communications to prevent accidents and increase safety. VII hopes to create a system that can warn the driver of imminent collisions, weather conditions, lane departures or unsafe curve speed, and also keep system operators informed of traffic conditions so they can better engineer traffic flow and prevent congestion (Vehicle Infrastructure Integration (VII), 2007).

The program integrates research being done by a variety of different groups. It builds on former work such as VSC, the Intelligent Vehicle Initiative (IVI) and the Enhanced Digital Map Project (EDMap). The National ITS Architecture (Version 6.0), which strives to create standard system specifications for ITS applications, has been updated to have better continuity with the VII program. The program will also make use of the technology being developed by the CICAS project.

The Michigan Department of Transportation (MDOT) was "allocated $45 million to develop and construct a test bed facility in Novi, Michigan, with an additional $25 million to develop and test the in-vehicle interface between the vehicle and the driver" (Smart cars and smart roads! Metro Detroit home to more than $70 million federal investment , 2007). MDOT is just one of a number of state DOT's involved in the project, including Minnesota, Florida, and California.

Currently, test equipment is being constructed, as well as planning for the testing in Michigan, which is a "proof of concept" set to assess 20 prototype applications. Business models, cost benefit analysis, and deployment strategies are being developed, and industry feasibility is being evaluated (Vehicle Infrastructure Integration (VII), 2007).

Transport Canada

The Canadian government is carrying out research in V2V communications and has looked into possible communication systems. The research arm of Transport Canada has investigated DSRC and Digital Audio Broadcasting (DAB) to transmit information over the L-band spectrum, which is processed into International Traveler Information Interchange Standards (ITIIS). A prototype system has been demonstrated. The possibility of monitoring cell phone signals from units in passing vehicles to determine traffic flow is also being investigated.

European Initiatives

Automatic Emergency Call (eCall)

The purpose of the eCall system is to reduce the number of automotive-accident fatalities by equipping cars to contact emergency services and report the vehicle's location. In concept, it will span Europe, and can be activated manually or automatically in the event of a crash. Mobile phone technology will be used to connect vehicles to Public Service Answering Points (PSAP's). The European Commission hopes to have all new cars in Europe equipped with eCall by the year 2010 (Research and Markets, 2007).

However, progress has been delayed. One reason for this is a lack of full support and coordination from member state governments, mobile service providers and automotive manufacturers, which is likely due to the lack of a strong positive business model. It is still unclear who will absorb the cost of installing and maintaining the system, and where profits will come from.

Nevertheless, some developments have been made. A demonstration by Continental Automotive Systems, Airbiquity, and Swissphone on March 6, 2007 was an end- to-end display

of a call from an automobile to an emergency center, which deployed rescue services (Continential Automotive Systems, 2007).

Central European Region Transport Telematics Implementation Coordination (Centrico)

Supported by the European Commission, the goal of the Centrico is to implement ITS to improve traffic flow on congested European highways. The project covers roadways in Belgium, England, France, Germany, Luxembourg, and the Netherlands. Centrico is one of seven European Commission groups supporting transportation initiatives across Europe.

Some of the projects include the Europe wide EASYWAY, which seeks to harmonize ITS development. Its focus is on "traffic safety, network performance, and [the] environment" (Centrico).

COMeSafety

As mentioned in Part I, the eSafety program is one of 3 pillars of the EU Intelligent Car Initiative, which has set the goal of cutting traffic fatalities in half by 2010. The program is sponsored by the European Commission's Department of Information Society and Media.

COMeSafety acts as the support for eSafety in the V2V and V2I communications area. Like Car2Car, COMeSafety is a mediator between various research and standards development efforts in Europe, while keeping up with activities in the United States. This project is set to run until December of 2009 (COMeSafety: Factsheet, 2006).

Cooperative Vehicle-Infrastructure Systems (CVIS)

The focus of CVIS is research related to the necessary communications systems for V2V and V2I networks. A router has been developed that can interface "mobile cellular, wireless local area networks, and infra-red to link vehicles continuously with roadside equipment and servers. The project wants to apply and validate the ISO 'CALM' standards for continuous mobile communication" (Kellum & Deegener, 2007). The CALM standard (Continuous Air interface for Long and Medium range) uses 5.8/5.9 GHz active infrared (Efkon, 2006). CVIS is projected to continue until January of 2010 (CVIS: Factsheet, 2006).

Co-Operative Systems for Intelligent Road Safety (COOPERS)

The focus of COOPERS (Co-Operative Systems for Intelligent Road Safety) is on using V2V and V2R communications to create a driving environment where up-to-date traffic and weather information is available in time for drivers to adapt, increasing safety and reducing congestion (Coopers). Coopers is slated to continue until January of 2010 (Coopers: FactSheet, 2006).

COVER

The COVER project objective is to create an ontology based system that allows for V2I communications and inoperable, semantic-driven cooperative systems. The use of communications will allow for shared information and the ability to put data into context and make the correct safety decisions. In addition, the goal is to develop applications such as intelligent speed adaptation to allow for dynamic speed limits. COVER is set to continue until February 2009 (COVER: Fact Sheet, 2006).

Global System Telematics (GST) Projects

GST has several projects aimed at developing safety telematics in Europe through V2V and V2I. Open Systems (OS) seeks to open the telematics environment by standardizing interfaces and architecture. Certification (CERTECS) is developing methods for telematics products to be certified as useable and reliable. Service Payment (S-PAY) is working on a standard, flexible method to pay for services. Security (SEC) is trying to ensure security in telematics. Rescue (RSQ) is trying to improve the quality of emergency services by providing accident information and location to rescue vehicles, use vehicle-to-vehicle communications to warn other drivers of approaching rescue vehicles, and allow for communication between the various branches of emergency relief (EMC, police, hospitals). Safety Channel (SAF-CHAN) is working on the process of communicating safety information such as traffic and weather conditions to drivers (GST, 2004).

PReVENT

PReVENT is a project funded by European automakers and the European Commission, and seeks to reduce the number of accidents through active safety systems. The ProFusion subproject was described in part 1. Three additional subprojects are described below.

SASPENCE: Striving for safe speeds and safe distance, this SASPENCE will evaluate driving conditions and suggest an appropriate speed and a following distance. The program also wants to use V2V communications to transfer obstacle warnings or emergency maneuvers to other drivers. One possible form of communication and sensing is 24 GHz radar. Later this could evolve into 77/79 GHz. It would have a sensing range of about 30 m and a communication range of about 200 m, and very short latency (Schulze, Gerhard, & Bohm, 2005). So far, functional requirements, system specifications, and a system architecture have been developed.

WILLWARN: The WILLWARN project seeks to develop vehicle-to-vehicle communications to increase driver awareness of local hazards such as accidents and poor road conditions. The goal is to have a system that can take sensor data, GPS positioning, and messages from other vehicles and create warning messages for the driver. Note that WILLWARN is not developing sensors or communication systems, but rather trying to apply them. For this, there are four (4) main modules: the Hazard Detection Module to take in data and classify hazards; the Warning Management Module for evaluating and handling messages; the

Communication Module to send warnings and receive warning from other vehicles; and the Hazard Warning module to warn the driver by sound (Schulze, Gerhard, & Bohm, June 2005).

INTERSAFE: INTERSAFE focuses on improving safety at intersections by mapping the vehicle's location and predicting the movement of other drivers, as well as sending signal information directly to the vehicle. Projected features include warnings for a driver who approaches a red light too fast and information on traffic light phases, so even someone seeing a green light can be warned if it will change soon and they will have to stop. The communication systems will likely be similar to that of the WILLWARN. A demonstration of an intersection safety application was held by INTERSAFE in April of 2006 (First Demonstartion of PReVENT's Advanced Intersection Safety Applications, 2006).

The INTERSAFE project successfully presented numerous intersection safety applications at the Advanced Microsystems for Automotive Applications (AMAA) conference on 25-27 April 2006 in Berlin. The project officially ended in January 2007.

SAFESPOT

SAFESPOT is an integrated research project co-funded by the European Commission Information Society Technologies. The goal is to develop a system called the Safety Margin Assistant, which makes drivers more aware of their surrounding environment and potentially dangerous situations. This is accomplished by using V2V and V2I communictations to extend the drivers horizon, and improve the speed and quality at which information is available. Key activities include using both vehicle and the infrastructure as sensors, developing a flexible modular architecture and communication platform, ad-hoc networking, relative localization techniques, and dynamic traffic maps (Objectives and Activities). In particular, the SAFEPROBE project is responsible for developing the architecture and use of on-board vehicle sensors, and also the interface and requirements for inter-vehicle communication and data fusion algorithms (SAFEPROBE - In-vehicle sensing and platform).

This project is set to run until January of 2010 (SAFESPOT: Factsheet, 2006).

SAFETEL

SAFETEL was a project that ran from January of 2004 to June of 2006, with the goal of enhancing "the susceptibility hardening of motor vehicles against electromagnetic (EM) disturbances;" the goals of this project were "to define the EM environment as a requirement for design, to reach a quantitative definition of immunity safety margins, to define EM hardening rules, and to define suitable test methods and procedures" (SAFETEL).

Watch-Over

The Watch-Over project is interested in protecting so called "vulnerable road users" such as pedestrians and cyclists through visual sensor recognition and short range communications systems. Project objectives are to select suitable communication systems and sensor

technologies, and then build system applications and test their performance. The end date is December of 2008 (Watchover: Fact Sheet, 2006).

The Watch-Over project investigated a number of communications strategies, most notably: IEEE 802.15.4, Bluetooth, WLAN (IEEE 802.11), WiMax (IEEE 802.16), Chirp Spread Spectrum (CSS – IEEE 802.15.4a), Radio Frequency Identification (RFID), and Ultra Wide Band (UWB). The project concluded that WiMax was not an effective strategy because it was not optimized for mobility, had large power requirements, and required complex, expensive equipment. RFID was eventually discarded, since its range was not sufficient to meet functionality requirements and its RSSI measurements were too environmentally dependent. UWB was described as very suitable for eSafety applications because of its high data rate its theoretically high accuracy of ranging. However, the authors indicated that there were no known UWB projects under eSafety. IEEE 802.15.4, Bluetooth, and 802.11 were also ruled out because of their inability to provide accurate ranging. For WATCH-over the conclusion was that CSS and UWB technologies seemed the most promising (Sikora, 2006).

National Projects

Network on Wheels (NoW) - Germany

NoW is a German research initiative supported by the Foreign Ministry of Education and Research. It was founded by European automakers, the Fraunhofer Institute for Open Communication Systems, NEC Deutschland GmbH and Siemens AG in 2004.

The focus of NoW's work is to deal with the technical and security issues related to protocols for V2V and V2I systems. Radio communications are based on the IEEE 802.11 standard and ad-hoc networking. The project hopes to support both safety and entertainment systems through wireless communications (Network on Wheels).

Some of the challenges faced by the group are the large size of the proposed network, the short time that vehicles have to communicate when traveling at high speeds, physical transmission challenges on the highway, and attempting to create ad-hoc nodes with "infrastructure-independent operation" (Gerlach, 2005).

Staufreies Hessen 2015 - Germany

This project was created to fight congestion in Hessen Germany, the English translation being 'Congestion Free Hessen for 2015.' It looks to use various ITS measures such as V2V and V2R communication to achieve better traffic flow control (Centrico).

Part of the Hessen initiative is DIAMANT (Dynamic Information and Applications to the Mobility safety device with Adaptive Networks and Telematics infrastructure). This project supports a lot of work in V2I communications with the help of local authorities. The idea is to provide services to users when the number of deployed units is low, which is much more difficult with V2V communications (Kellum & Deegener, 2007).

The Hessen project was also a test bed for the GST EFCD research described above, which included an algorithm tailored to detect traffic congestion (Burkert, 2006).

Applications of Integrated Driver Assistance (AIDA) – The Netherlands

AIDA (Applications of Integrated Driver Assistance) is a research program started in 2003 and conducted by the University of Twente in association with the company TNO. Research is carried out primarily by doctorial students at the university. The goal is to gather information about what users want from ITS, and predict the effects that these new systems will have on traffic flow and drivers. The program also does research into the design of algorithms to support such services, such as how use road way information to predict travel time. Lastly, the group looks into possible advantages of vehicle guidance through V2I communication (Applications of Integrated Driver Assistence (AIDA)).

INFONEBBIA "Safety in the Fog" – Italy

This project is carried out by ANAS, the Italian Roads and Highway Association. Its goal is to design and test a V2I system that will improve driving in poor visibility. Two preliminary experimental sites, both 10 km long, have been installed.

The system is based on various sensors (cameras, radar, temperature, humidity) whose data is combined to determine visibility conditions. In adverse conditions, drivers can be warned of fog, accidents, queues, chances of ice, and recommended maximum speed. Smart Cars can be deployed with advanced anti-collision and messaging systems to guide private vehicles through the fog safely. Also, light guides can be modified to better assist drivers, and LED warning boards can change their lighting schemes based on external conditions (Alampi, 2007).

Asian Projects

EU-India eSafety Cooperation

The goal of EU-India is to deploy the advanced traffic and safety systems developed by the eSafety project in India. This is also a chance for the EU to launch research in India and support collaboration between experts in the involved countries. This will improve safety on India's roads and open up economic opportunities for European businesses (Background and Objectives).

Japanese ITS

Initiatives in ITS are headed by the Japanese Ministry of Land, Infrastructure and Transportation. Nine main goals have been outlined for the deployment of ITS systems in Japan: advanced navigation systems, electronic toll collection, assistance for safe driving, optimization of traffic management, increased efficiency in road management, support for public transport, increased efficiency in commercial vehicle operations, support for pedestrians, and support for emergency vehicle operations.

Advanced Cruise-Assist Highway System Research Association

The Advanced Cruise-Assist Highway System Research Association (ACHSRA) is often referred to simply as AHS. This project seeks to reduce accidents on Japan's roadways by addressing the three main pre-crash factors: errors in recognition, errors in judgment, and errors in operation. Technology is aimed at supporting the driver in basic maneuvers such as intersection crossings and turns, merging on the highway, and driving safely on curves. The systems try to prevent lane departures and pedestrian collisions and they provide road condition information.

The main objectives are working towards zero fatal traffic accidents, support for elderly drivers, and reduced congestion. Notably, there is also an objective to collect information from vehicles and identify dangerous situations, such as rapid deceleration and icy road conditions (Conceptual Image of Targeted Services for Realization, 2005). Vehicle-to-vehicle communications is listed as a future goal of this initiative. Other targets are extensive testing and verification by 2008 and nation-wide deployment of ITS systems in high accident areas by 2010 (AHS Roadmap, 2005).

Since 2002, AHS has been conducting field experiments. In one test, conducted May 2005 in the Sangubashi section of the Metropolitan expressway No. 4, V2I communications warned drivers of traffic congestion around a sharp curve using navigation systems. The results showed a 12.2% reduction in hard braking occurrences, a 14.3% drop in high speed approaches, and a 60% drop in accidents (The FOT on the Sangubashi Curve, Tokyo Metropolitan Expressway, Confirms AHS Effectiveness, 2005).

Vehicle Information Communication System (VICS)

VICS is a service that provides real time traffic updates to equipped navigation units. Information provided includes traffic congestion, travel time, location of accidents and roadwork, speed and lane regulations, parking lot locations and availability. Traffic information collected by road administrators and police headquarters is sent to the Japan Road Traffic Information Center. The data is then passed on to a VICS center, which processes it into an easy to understand, location specific form. This information is forwarded to the vehicles by one of three methods: infrared beacons on main roads, radio-wave beacons on expressways, and FM multiplex broadcasts over large areas (VICS Brochure).

Internet ITS Consortium

This Japanese industry group seeks the development of ITS applications in Japan by making a wide range of internet information available to drivers,

SMARTWAY 2007

SMARTWAY 2007 is a service trial of Japanese ITS systems set for October 15 to 17, 2007 on the Metropolitan Expressway. Trial rides and exhibits will show the progress made in ITS. Services which will be tested are:

- o Information for assisting safe driving using roadside sensors to provide drivers with information on congestion and obstacles around blind curves;

- o Still image information from road side cameras provided to drivers in the form of stills;

- o Collection of road condition data through V2I communication;

- o Merging Assistance using DSRC communications to detect vehicles in the main lane, and warn drivers in the merging lane using V2I communication;

- o Parking lot cashless payment;

- o Internet Connection (SMARTWAY 2007, 2006).

The driver interface will be either through an independent ITS on-board unit that provides audio warnings, or visual information will be integrated into equipped navigation systems. As of December 2006, 17 million VICS units have been shipped (Current Progress of ITS, 2007). The VICS units are those capable of receiving real time traffic updates.

Information will be transmitted through 5.8 GHz DSRC (audio and visual data) or 2.5 GHz (visual only). Internet access will also be available through wireless LAN (Introduction of Japanese SMARTWAY 2007, 2007). The lower layer communication protocols are listed as DSRC-L1 and DSRC-L2 9 (The Outline of the Road Communication Standard).

DSRC (Designated Short Range Communications)

Arguably the most proposed form of vehicle-to-vehicle communication in the United States is DSRC. DSRC systems are being designed to operate in the 5.9 GHz band allocated by the FCC for vehicular communications. The system is based on current 802.11 standards, though work is being done to optimize it for the vehicular environment. This includes low latency for safety applications, ability to work at high speeds, prioritization, and ensuring driver anonymity while protecting message integrity (Roebuck, 2005). Technical concerns include the high relative speeds between vehicles, the need for reliability in safety systems, and the sensitivity of 5.9 GHz signals to shielding (Kellum & Deegener, 2007).

There is an effort to split DSRC into five layers: the application layer, the transport layer, the network layer, the link layer, and the physical layer. Algorithms are also being developed for relative positioning, store forward, multi-hopping, ad hoc networking, congestion control, power control, and channel switching (Kellum & Deegener, 2007).

In a report prepared for the U.S DOT, the following technical parameters of DSRC were listed: vehicle speed up to 120 mph; nominal range of 300 m and up to 1000 m for specialized

applications; latency of less than 50 ms; nominal data rate of 6 Mbps, up to 27 Mbps; single transaction size of up to 20 kbytes (SIRIT Technologies, 2005).

Allocated Bandwidth for DSRC

In North America

The FCC has allocated 75 MHz of bandwidth at 5.9 GHz (specifically 5.85-5.925 GHz) for DSRC automotive communications. The band is intended to be used for public safety vehicle alerts but can be licensed by non-government sectors for applications not related to safety (Dedicated Short Range Communications (DSRC) Service, 2007).

The ATSM E221-03 standard breaks up the bandwidth allocated by the FCC into seven 10-MHz channels, including "a dedicated control channel for announcements and warnings, a high availability, low-latency channel, and multiple service channels" (Carter, 2005).

Industry Canada has allocated the same band as the FCC for DSRC ITS applications (St-Aubin, 2007).

In Europe

Bandwidth in Europe is controlled by the European Telecommunications Standards Institute (ETSI) and the Electronics Communications Committee (ECC). As of yet, a frequency has not been formally allocated. What is being considered is a band from 20-70 MHz, also in the 5.9 GHz frequency range. A notable difference from the American standard is that the European bandwidth request is divided by function, with 20 MHz requested for "Critical Road Safety," 30 MHz for "Road Safety and Traffic Efficiency," and 20 MHz for "Non-Safety" functions. The number of these bands that are eventually approved will determine the overall final bandwidth and also how closely the European system will mirror the American system. If only the 20-MHz critical band is granted, design differences between the two will be significant (Kellum & Deegener, 2007).

North American Standards Development

IEEE Standard 802.11p

The 802.11p, or Wireless Access in the Vehicular Environment (WAVE), standard for wireless communications is a modified version of the commonly used 802.11a standard. It is still being developed by IEEE and has a projected approval time of May 2009 (IEEE 802.11 Official Timelines, 2007). It covers the physical and the MAC layer.

Though the standards are not yet complete, there is potential for research and development based on available standards and hardware. On their website on DSRC Communications, IEEE states, "The differences between existing 802.11a products and the final DSRC compliant products will have little significance to probably 95% of any program. The systems can go through the whole development and testing process, and the standards compliant hardware

changed over at a later time just before full deployment/system release" (DSRC: North America).

IEEE P1609.1,2,3,4

Called the Upper Layer WAVE Standards, the P1609 family is responsible for the upper layers of DSRC. The standards define the following: P1609.1 – WAVE Resource Manager; P1609.2 – Security Services for Applications and Management Message; P1609.3 - Networking Services ("IP Interface"); P1609.4 – Multi-Channel Operation ("MAC Extensions") (Roebuck, 2005).

Like 802.11p, these standards are under development. Version 1 was published in May of 2007 (News: Updated Standards Statuses, 2007).

SAE Safety Message Set

The Society of Automotive Engineering is responsible for creating a standard safety message set to be used with DSRC, known under document number SAE J2735. The protocol "defines the message payload at the physical level", with the lower levels falling under IEE 802.11p and the upper levels under IEEE P1609 (ITS Standards Fact Sheet, 2006). Version 1 of the document was published in January of 2007, and Version 2 of this document is under development (News: Updated Standards Statuses, 2007).

Notable Differences between the North American and European Systems

Bandwidth

As explained in the above section on bandwidth, the European system has yet to allocate a band for vehicle-to-vehicle communications. Also, there is a chance that the bandwidth in Europe will be less than the 75 MHz set aside in North America, forcing the DSRC designs to diverge considerably.

ISO Standards in DSRC

The ISO has two subcommittees that work with DSRC. WG15 has primary responsibility for DSRC, and its definitions vary in range and speed from those of their North American counterparts. Also, the group is developing a standard for an Application Layer, which is also not currently in use for the North American 5.9 MHz band. However, WG16 also has proposed some DSRC features that are a close match to those of the North American system (DSRC: North America).

Part III: Economic Factors

The Market Penetration Problem

In contrast to safety systems like seat belts and airbags, which have stand-alone benefits to the driver, the nature of vehicle-to-vehicle communications requires many units to be equipped with them for the technology to be effective. For example a system set to warn the driver if another vehicle is running a red light will be ineffective if either unit is not equipped to communicate with the other.

In studies conducted by GTS on Floating Car Data (FCD), the prediction was that 2-3% of on-road vehicles must be suitably equipped for the data collection to be effective (Burkert, 2006).

Market penetration requires public support through a strong perception of benefits to the consumers. Also a positive business model is needed for private industry to invest in this technology. This is not yet fully developed. Currently "the benefit analysis revolves around safety and traffic efficiency" (Kellum & Deegener, 2007). A cost advantage to a system using an 802.11 standard is that inexpensive, mass produced consumer electronics are already being produced for this protocol. The cost will increase if it is found that these are not suitable in automobiles, and additional design work is needed.

However, even before sufficient market penetration has been reached, vehicles with on-board sensor and communication capabilities can be used in data collection to evaluate system performance and to create a general knowledge base. Also, should several equipped vehicles happen to be in the same area, a properly designed system will still provide safety benefits (Burkert, 2006).

Additional Obstacles in Europe

There are additional obstacles to creating a standardized ITS system in Europe that are not present in North America. In North America there are only 3 major countries (US, Mexico, and Canada), with the U.S. decidedly the dominant player both politically and economically. There are 15 member states in the European Union, with no centralized governing body, and no similarly dominating member. Even when a standard is passed by the European Telecommunication Standards Institute (ETSI) and the Electronics Communication Committee (ECC) it must then be accepted by the individual nations.

The lack of a politically dominating state in Europe is mirrored by the lack of a dominant economic force in the auto industry. In 2005, the top four automakers in the U.S. (by market share) were GM (28%), Ford (20%), DaimlerChrysler (15%) and Toyota (13%). In Europe, the top four were Volkswagen (18%), PSA (14%), Japanese automakers (14%) and Ford (11%) (Kellum & Deegener, 2007). Since the effectiveness of vehicle-to-vehicle communications will likely depend on the percentage of equipped vehicles, there is an advantage in the United States where the market is more concentrated. If the top two U.S. automakers were to install V2V communication systems on all of their retail vehicles, that would account for 48% of new cars

sold. In Europe, Volkswagen and PSA command only 32%. It will likely be easier to have a timely deployment in the U.S that in Europe.

Advantages and Disadvantages of On-Board Data Collection

The advantage of on-vehicle traffic data collection is that the installation and maintenance costs of such a system would be less than that of equivalent infrastructure sensors. Also the mobile nature of the sensor network allows it to cover a much larger area, including rural areas where infrastructure sensors are not practical. Even in areas where road sensors exist, vehicle data could act as additional validation. Another advantage is that information collected and processed in the vehicle has the potential for a much faster delivery to the customer.

A prohibiting factor, in addition to the market penetration problem addressed above, is the lack of good field experience using data gathered by vehicles. Also, consumers might feel threatened at the idea of being constantly monitored by a third party while driving. Lastly, equipment costs could be a still roadblock. Market studies have shown that there is an unwillingness to pay for telematics services among consumers (Burkert, 2006).

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