VEHICLE TO VEHICLE COMMUNICATION FOR CRASH AVOIDANCE SYSTEMS

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1 INTRODUCTION

1.1 CONCEPT OF VEHICLE-TO-VEHICLE COMMUNICATION

In recent years, as an instance of vehicular ad-hoc network, the telematics integrating the utility of telecommunications and informatics has dramatically promoted the development of wireless communications in vehicular environment, intelligent transportation system, and automotive electronics industry. The further extension of WAVE (Wireless Access in Vehicular Environments) technology is dedicated short range communication (DSRC). These networks are characterized by rapidly changing topologies and shorter connection lifetime, and one of the most essential goals of the emerging DSRC based V2V communication standards is to enable road safety applications that can save thousands of lives. Safety-related applications are primarily geared toward avoiding the risk of car accidents such as cooperative collision warning, lane change, emergency vehicle approaching warning, pre-crash sensing, traffic violation warning.

These applications all have real-time constraints, which always rely on single or multi-hop V2V communications. Moreover, the quality of vehicle safety applications smoothly degrades with the increase in packet loss and delays in vehicular wireless communications. Especially, timely warning messages transmitted by a braking or slowly moving vehicle enable approaching traffic to take appropriate actions such as slowing down and changing lanes, much earlier than is possible, thereby reducing the chance of crashes or chain collisions. The strict performance for delivery delay and reliability of V2V communication systems with DSRC should be imposed to meet the requirements of traffic safety applications.

In vehicular communication network types, the transferred information contains warning messages and traffic information. Vehicular communication systems are effective in decreasing the accidents and traffic congestion. Due to the importance of road safety in recent years, the research on Vehicle-to-Vehicle (V2V) communication is increasing. IEEE 802.11p defines an international standard for wireless access in vehicular environments (WAVE). Generally wireless access in vehicular environments contains two different types of networking which are V2V and V2I, vehicular

Figure 1: Vehicles communicating each other with their own ad-hoc networks
communications I categorized as a part of Intelligent Transport Systems (ITS). In addition, Vehicular communication networks will offer a wide range of applications such as traffic management, road conditions.

The Vehicle to Vehicle (V2V) is a combination of three networks: an inter-vehicle network, an intra-vehicle network, and vehicular ad-hoc network. Based on this concept of three networks combined to form one, we define Vehicle-to-Vehicle as a large-scale distributed system for wireless communication and information exchange between surrounding vehicles according to agreed communication protocols and data interaction standards. It is an integrated network for supporting intelligent traffic management, intelligent information service, and intelligent vehicle control, representing a typical application of Internet of Things (IoT) technology in intelligent transportation system (ITS).

To succeed in this emerging market, acquisition of core technologies and standards will be important. However, the integration of the V2V with other infrastructures should be as important as the building of the V2V technologies themselves. As a consequence of this, the V2V will become an integral part of the largest Internet of Things (IoT) infrastructure by its completion.

Figure 2: Trajectory Prediction in V2V
1.2 OPPORTUNITIES AND CHALLENGES OF V2V

The research and development, as well as the industrial application of V2V technologies will lead the integration of automotive and information technology. The integrated information services of vehicles, vehicle safety, and economic performance will contribute to a more intelligent urban transportation system development. The V2V will impact on the consumer vehicle market, consumer lifestyle, and even modes of behavior. The future V2V market will see rapid growth in the Asian-Pacific region. McKinsey Global Institute has reported by June 2013 that the Internet of Things (IoT) has the potential to launch around $6.2 trillion in new global economic value annually by 2025. 80 to 100 percent of all manufacturers will apply IoT technology by then, leading to potential economic impact of $2.3 trillion for the global manufacturing industry. According to the data on APEC website, the member countries share approximate 55 percent of world GDP. In other words, APEC members will be growing by $3.42 trillion in GDP and manufacturers of the economies will embrace $1.27 trillion growth in the meanwhile.

The application of V2V technology in providing information services, improving traffic efficiency, enhancing traffic safety, implementing supervision and control and other aspects will make millions of people enjoy more comfortable, convenient and safe traffic service. Large concentrations of vehicles, e.g., in city parking facilities during business hours, can also provide the ad-hoc computational resources which will be of interest to those in the IT fields. Complementary efforts should be made for developing and enhancing middle-ware platforms which will enable analytic and semantic processing of data coming from vehicles. Lack of coordination and communication is the biggest challenge to V2V implementation. Lack of standards make effective V2V (vehicle to vehicle) communication and connection difficult and prohibits ease in scaling. Only by adopting open standards can the current, closed and one-way systems, be integrated into an effective system for the smooth sharing of information. Dreams of intelligent transportation and even automatic drive systems can come true through an effective V2V. Both technological innovation and business model innovation in the Internet era depend on partnering across traditional boundaries. While maintaining a plan for improving products, services and experiences, we should make joint efforts to break barriers, stay open and inclusive, and to build a healthy and sustainable ecosystem. Efforts should be made to promote the application of V2V and relevant technologies in automobiles, transportation, finance and insurance.

Progress towards ubiquitous V2V systems will need to be conducted in stages, starting with low-risk, simple implementations, and learning from these to plan and design wider systemic deployments. For example, computer-augmented control of vehicle movements and collision avoidance systems would be tested and improved in closed environments, such as warehouses, then implemented more widely between specialized driver less vehicles on some targeted roads, before wide deployment to public and private transport for entire cities. Data linkages would start with basic information exchange, such as traffic information or number of vehicles in the vicinity, passenger numbers, locations or travel routes, before progressing to two-way communication, active traffic management and external control over functions of vehicle. The data sets generated by operational V2V systems will be rich and diverse, and will constitute a valuable resource in their own right. For this, the data has to be considered not as a ‘consumable’ or ‘disposable’ to meet immediate needs of V2V users, but as an accumulating economic and scientific resource, with many potential future users. Such massive data sets can provide a basis for research in many other disciplines, not only for the development of V2V systems, or the monitoring and management of vehicles, traffic, road systems and their economic impacts or industrial development.
1.3 V2V TECHNOLOGY PRODUCTS

Cohda’s technology integrates wireless communications to quality levels far beyond commercial off-the-shelf IEEE 802.11p transceivers, which allows cars to more potentially “see” through obstacles or around corners. Autotalks has V2X solutions in forms of integrated SoCs combining processing, RF and GNSS components. NXP, as leading global supplier of car radio semiconductors and security chips, brings its software-defined radio (SDR) platform and ensures more improved parameters such as industry-ready data security, cost efficiency, form factor, power consumption, and performance. Together, Cisco, NXP, and Cohda plan to develop a complete ready to market solution for the automotive industry. Cohda wireless is one of the leading Cooperative Intelligent Transport Systems (ITS) use both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, and thus a combined system called V2X - to enable cooperation between vehicles and road infrastructure in order to get improvements in the areas of safety, mobility, and the environment. The aim of Cooperative-ITS is to create wireless communications links between smart vehicles and between these vehicles and smart roads, in order to allow them to communicate with each other and so avoid accidents, reduce congestion and be more efficient. V2X Connected Vehicles will use several types of wireless connectivity for the transmission of safety messages e.g. cellular, Wi-Fi, or DSRC.
2 V2V IMPLEMENTATION DETAILS

2.1 THE BASIC SAFETY MESSAGE

The Basic Safety Message is the primary message set to send data between vehicles. While the BSM is mainly developed for safety applications, the data in the message may also be used by other connected vehicle applications, such as mobility, weather, etc. Additional messages from vehicles or from the infrastructure may also be created in the future.

The second version of the standard SAE J2735 is published in November 2009, which is very recent. It specifies 15 message sets, with Basic Safety Message the most important one. As explained above, the BSM is used to exchange safety data regarding state of vehicle. The message is broadcasted commonly to surrounding vehicles with a variety of data content. The BSM is categorized into two parts to guarantee that the core information for vehicle safety (Part I) has priority and is transmitted more often. It also minimizes the amount of data communicated (most of the time) between devices, helping to reduce channel congestion. [1]

BSM Part I contains the core data elements, such as vehicle position, speed, heading, brake system status, and vehicle size. Details of the BSM Part I contents are found in Table 1.

<table>
<thead>
<tr>
<th>BSM Part I</th>
<th>Data Element (DE)</th>
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<tbody>
<tr>
<td>Data Frame (DF)</td>
<td>Latitude</td>
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<td></td>
<td>Elevation</td>
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<tr>
<td></td>
<td>Longitude</td>
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<td></td>
<td>Positional accuracy</td>
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<tr>
<td>Motion (DF)</td>
<td>Transmission state</td>
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<td></td>
<td>Speed</td>
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<td></td>
<td>Steering wheel angle</td>
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<td></td>
<td>Heading</td>
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<td></td>
<td>Longitudinal acceleration</td>
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<td>Vertical acceleration</td>
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<td></td>
<td>Lateral acceleration</td>
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<tr>
<td></td>
<td>Yaw rate</td>
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<td></td>
<td>Brake applied status</td>
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<td>Traction control state</td>
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<td></td>
<td>Stability control status</td>
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<td></td>
<td>Auxiliary brake status</td>
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<tr>
<td></td>
<td>Brake status not available</td>
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<tr>
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<td>Antilock brake status</td>
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<tr>
<td></td>
<td>Brake boost applied</td>
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<tr>
<td>Vehicle size (DF)</td>
<td>Vehicle width</td>
</tr>
<tr>
<td></td>
<td>Vehicle length</td>
</tr>
</tbody>
</table>

Table 1: Contents of BSM Part I [1]
2.2 WIRELESS ACCESS TECHNOLOGIES

The suitability of various wireless access standards to support VANET applications including infotainment applications are compared in terms of Bandwidth, Signal coverage, Signal Interference, Accessibility, Maintenance, Upfront cost and Security. The data transmission rate determines the amount of data transmitted between the ends of communication at a time. Infotainment applications such as large data transfers, video chat, needs more bandwidth. Signal coverage which determines the service area is essential for the deployment of specific standard. It is measured using signal strength and propagation path loss caused by factors like multipath propagation, reflection, absorption and diffraction. Signal interference decreases coverage range and throughput. Accessibility determines the number of simultaneous data transmission of multiple users so as to improve bandwidth utilization. Maintenance deals with the life of network whereas upfront cost covers the total costs of acquisition. The last parameter addresses how wireless standard protect communications over a shared wireless medium. Based on these parameters a comparison of various available wireless standards is shown in the following table 2.

![Table 2: Comparison of Wireless Access Technologies](image)

Based on the comparison, DSRC/WAVE is considered to be best suited for Safety critical application.
2.3 TECHNOLOGY IMPLEMENTATION

To generate and send a Basic Safety Message, a device must know its own position (such as via a GPS antenna and receiver). Once its position is known, the device needs a computer processing unit that can take its location and can combine it with other on board sensors (e.g., speed, heading, acceleration, breaking) to generate the required BSM data string. Once the BSM is generated, a device needs to transmit this message wirelessly to another vehicle. As the on board processor is generating the BSM, a security module is processing and preparing the security information and certificates for transmission to provide the receiving vehicle assurance that the message is valid. This security information needs to be transmitted wirelessly as well. To receive and interpret a BSM, a device must be capable of receiving the BSM that is transmitted from a nearby device and it must match the method of BSM transmission (i.e., if the message is transmitted via RF, the receiving device must have a RF receiver). It also must have an assembly that can decode the BSM properly. A GPS antenna and receiver is needed to verify the relative distance between the sending device and the receiving device. The BSMs follow SAE J2735 standard frame structure. SAE J2735 is intended to address the purpose so that all V2V safety applications are built around a common framework. SAE J2735 defines the design specifications for the safety messages, including specifications for the message sets, data frames, and data elements. Lastly, the device that is receiving the BSM must also have a security module that is capable of receiving and processing the security credential information as well.

![Figure 3. Block Diagram of V2V Communication Assembly](image)

For transfer of BSMs, a secured and reliable communication medium is necessary. There are many communication networks available for VANETS. These communication standards transfer packets of data without the use of any deployed infrastructure.
2.4 DEDICATED SHORT RANGE COMMUNICATION (DSRC)

Dedicated Short Range Communication (DSRC/IEEE 802.11p) was exclusively developed to meet the requirements of VANETs such as self-organizing, self-configuring, high mobility and dynamic topology. DSRC works using a 75MHz spectrum in 5.9 GHz frequency band in US whereas in Europe and Japan it operates on 30MHz spectrum in the 5.8 GHz band. It can provide services to both V2V and V2I up to 1km and supports data rate of up to 27Mbps. As shown in the Figure 4 the spectrum comprises a 5MHz guard band, one 10MHz Control Channel (CCH) and six 10 MHz Service Channels (SCHs).

In DSRC, On Board Units (OBU) communicate using either 802.11p or Wireless Access in Vehicular Environment (WAVE) standard. Usually DSRC and WAVE term are used interchangeably. The notable differences are that DSRC includes IEEE 802.11p, an amendment of 802.11a MAC and PHY whereas WAVE standard focused on the upper layers. Furthermore, DSRC can use the WAVE Short Message Protocol (WSMP) to support V2V and V2I safety applications. The following Figure 5 shows the Layered architecture of DSRC. The MAC Layer is divided into two layers: MAC sub layer and Logical Link Control (LLC). The MAC sub layer allows Stations (STAs) to share the spectrum more effectively and uses IEEE1609.3 standard to support multi-channel operations of DSRC by extending MAC functions. LLC uses 802.2 along with Sub Network Access Protocol (SNAP) to provide services required by higher layers including 1609.3. Based on the requirements of VANET applications, the Network and Transport Layer uses protocols such as IPv6, TCP, UDP and WSMP to facilitate wireless connectivity. Typically, it uses WAVE Short Message Protocol (WSMP) for single hop transmissions and the remaining protocols for supporting multihop transmissions. Its architecture can support both safety and non safety applications using WSMP and TCP/IPV6 respectively. The P1609.3 standard provides networking services and defines WSMP and WAVE Service Advertisement (WSA). The application layer comprises applications and some other to support inter operability among the safety applications.

IEEE P1609.1 - Resource Manager
IEEE P1609.2 - Security Services for Applications and Management Messages
IEEE P1609.3 - Networking Services
IEEE P1609.4 - Multi-channel Operations

DSRC is widely and chiefly used for road safety applications due to its reliability, secure data transmission and low latency. DSRC standard is still a draft because of some technical issues that need to be addressed before the full adaption for VANETs. It has been observed that the current specification of DSRC performs poorly in high density and mobility conditions. Protecting safety related and application messages against abuses is another issue in DSRC. DSRC is mostly used for Electronic Toll Collection (ETC) in various countries such as Italy and Germany.

![Figure 4. DSRC Channels](image)

![Figure 5. DSRC Architecture](image)
3 PROJECT OVERVIEW

At eInfochips, we have tested a prototype implementation of a complete vehicle to vehicle communication, designed according to the BSM I specification SAE J2735. The purpose of this project is to prove feasibility of V2V to improve safety of transportation systems. Road safety can be enhanced by the deployment of wireless communication technologies for vehicular networks, which activates new services such as collision prediction, traffic management and further communication facilities between nearby moving vehicles. In addition to this a blind spot detection system for protection against vehicle collisions is being implemented. The blind spot detection system is useful while changing the lanes.

The activities were performed in following key milestones –
- Design of path prediction algorithm and use cases of V2V communication
- Testing of hardware modules
- Interfacing the required hardware with the embedded platform
- Scripting for standard message frame structure SAE J2735
- Integration of scripts to form a single software module

3.1 HARDWARE ARCHITECTURE OF V2V PROTOTYPE

The block diagram of V2V communication is as shown in figure 1. GPS module provides information about speed, location of vehicle, and path of the vehicle to the On Board Unit (OBU). We have implemented a prototype of V2V communication system in which, we have chosen raspberry pi as an on board unit, which processes the data provided by GPS. It generates the safety messages depending on the position of the vehicles. The safety messages are transmitted and received by RF transceiver module as depicted in Fig.1. Basic safety messages are displayed on the display unit. In general, two sets of components are needed for V2V communication to operate. The first set of components are those required for a device to transmit an accurate and trusted basic safety message and the second are the components needed for a device to receive and interpret a BSM transmitted from another entity.

Figure 6. Hardware Architecture
Figure 7. System Implementation
REFERENCES


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