Vehicle to Vehicle Wireless Communication Protocol for Collision Warning

A Seminar Presentation
by

Arunkumar Anand
Roll no: 2 , S_7 ECE
GEC, Wayanand

In the Partial Fulfillment
Of the Requirements for the Degree of
B.Tech in Electronics & Comm. Engineering

Dept. of Electronics & Communication Engineering
Government Engineering College, Wayanad

28 September 2006

Acknowledgements

First of all let me thank our HOD Prof. Hari, Department of ECE for insisting us to choose better topic in the seminar presentation. He made us to select currently relevant applications particularly on communication field by referring us to well reputed international journals such as IEEE Communication Magazine.

Then, Let me show my sincere gratitude to our Lecturer Rajeev Rajan, Dept. of ECE, the person behind the successful completion of our seminar. Rather than being our Seminar coordinator he sincerely helped us in each stage of our seminar developments. He recommended us to make the seminar reports in LaTeX an internationally accepted typesetting tool particularly for scientific presentation.

Again I'm obliged to my parents and my sister for giving me freedom and support in the entire endeavor for the completion of my seminar.

Above all I'm grateful to the supreme grace, without his help I couldn't accomplish anything.

Abstract

This article presents an overview of recently developing vehicular communication technology particularly describing Vehicle to Vehicle (V2V) communication using IEEE and ASTM adopted Dedicated Short Range Communication (DSRC) Standard. This paper also discusses some of the application requirements and congestion control policies. Lastly, a real life implementation of V2V and DSRC standard that support it are analysed.

Contents

List of Figures

List of Tables

1 Introduction

Traffic accidents have been taking thousands of lives each year, outnumbering any deadly diseases or natural disasters. As far as India is considered, India having less than 1% of the world's vehicles, the country accounts for 6% of total road accidents across the globe and 10% of total road fatalities [13]. Every year in the United States, about six million traffic accidents occur due to automobile crashes. In 2003 alone, these accidents accounted for $230 billion in damaged property, 2,889,000 nonfatal injuries, and 42,643 deaths [14]. While different factors contribute to vehicle crashes, such as vehicle mechanical problems and bad weather, driver behavior is considered to be the leading cause of more than 90 percent of all accidents. The inability of drivers to react in time to emergency situations often creates a potential for chain collisions, in which an initial collision between two vehicles is followed by a series of collisions involving the following vehicles.

Studies [15] show that about 60% roadway collisions could be avoided if the operator of the vehicle was provided warning at least one-half second prior to a collision.

1.1 Human driver's limitations

In emergency situations, a driver typically relies on the tail brake light of the car immediately ahead to decide his or her own braking action. Under typical road situations, this is not always the best collision avoidance strategy for various reasons. In many cases, the ability to detect an emergency event occurring at some distance ahead is limited by the inability of drivers to see past the vehicle in front of them.

Human drivers suffer from perception limitations on roadway emergency events, resulting in large delay in propagating emergency warnings, as the following simplified example illustrates. In Figure 1.1, three vehicles, namely A, B and C, travels in the same lane. When A suddenly breaks abruptly, both vehicles B and C are endangered, and being further away from A does not make vehicle C any safer than B due to the following reason.

Figure 1.1: V2V Helps to improve road safety.

- Line-of-sight limitation of brake light: Typically, a driver can only see the brake light from the vehicle directly in front. Thus, very likely vehicle C will not know the emergency at A until B brakes.

- Large processing/forwarding delay for emergency events: Driver reaction time, i.e., from seeing the brake light of A to stepping on the brake for the driver of vehicle B, typically ranges from 0.7 seconds to 1.5 seconds [16],[2], At a speed of 70 mph, this means that between 75 and 150 ft is traveled before any reaction occurs; which results in large delay in propagating the emergency warning.

1.2 Need of Intelligent Transportation System (ITS)

Chain collisions can be potentially avoided, or their severity lessened, by reducing the delay between the time of an emergency event and the time at which the vehicles behind are informed about it [4]. One way to provide more time to drivers to react in emergency situations is to develop Intelligent Transportation System applications using emerging wireless communication technology. The primary benefit of such communication will be to allow the emergency information to be propagated among vehicles much quicker than a traditional chain of drivers reacting to the brake lights of vehicles immediately ahead.

Figure 2 details the system architecture proposed by the U.S. Department of Transportation U.S. DOT, 2003) for the development of Intelligent Transportation Systems (ITS) [17]. The architecture is defined around four basic components linked by a communication infrastructure.

The four generic types of telecommunications systems are:

- Vehicle-to-Vehicle

- Dedicated Short Range Communications (DSRC)

- Wide Area Wireless

- Wireline

Wireline and Wireless are the two primary types of telecommunications architectures shown in the diagram, with Vehicle-to-Vehicle (V2V) and DSRC being two applications of wireless. There is no distinct requirement to use RF, Copper, or Fiber Optics as a transmission medium. Nor is there any suggestion as to the network topology: point-to-point, star, ring, mesh, etc. More recently, the combined availability of the Global Positioning System

(GPS) and deployment of cellular-based communication systems has further fueled the development of vehicle tracking systems and systems providing information to travelers in vehicles through wireless means. Interest in vehicle-to-infrastructure and vehicle-to-vehicle communication capabilities has only recently gained momentum, as such capabilities were in the past either not technically feasible or too costly to implement and operate.

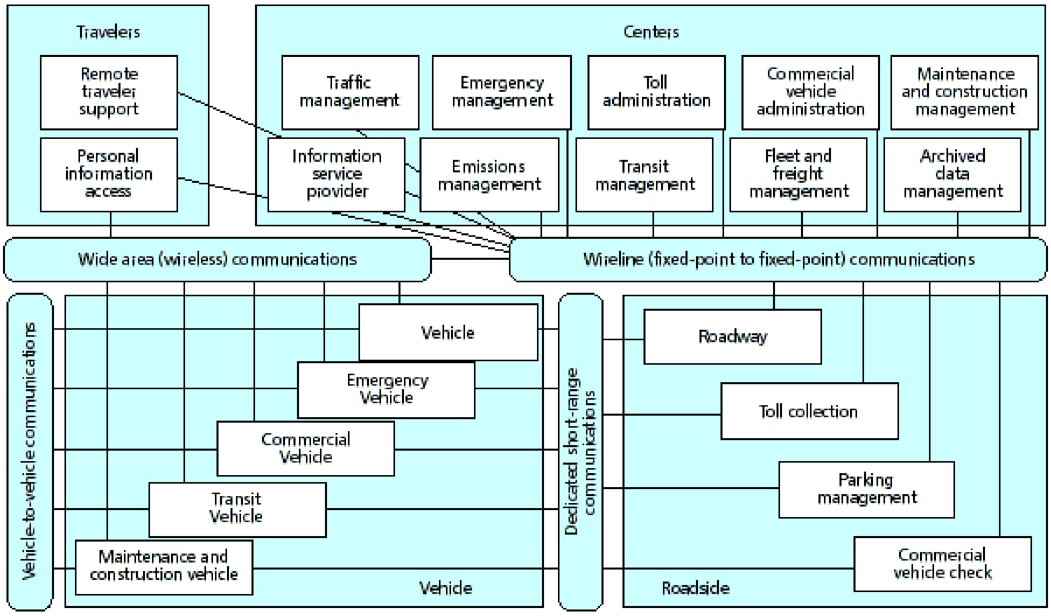

Figure 1.2: Proposed national ITS architecture (U.S. DOT, 2003)

Road and traffic safety can be improved if drivers have the ability to see further down the road and know if a collision has occurred, or if they are approaching a traffic jam. This can become possible if drivers and vehicles communicate with each other and with roadside base stations. If traffic information was provided to drivers, police, and other authorities, the roads would be safer and traveling on them would become more efficient. It is possible to build a multihop network among several vehicles that have communication devices. These vehicles would form a mobile ad hoc network, and could pass along information about road conditions, accidents, and congestion. A driver could be made aware of the emergency braking of a preceding vehicle or the presence of an obstacle in the roadway. Even though the topic is too big, here in my seminar, I made an endeavor to present an overview of vehicular communication technology particularly describing V2V communication using IEEE and ASTM adopted DSRC Standard. This paper also discusses some of the application requirements and congestion control policies.

2 Next Generation Vehicular Scenario

Now the vehicle manufactures are making vehicle with sixth sense. Using vehicle-to-vehicle (V2V) communication, a vehicle can detect the position and movement of other vehicles up to a quarter of a mile away. In a world where vehicles are equipped with a simple antenna, a computer chip and GPS (Global Positioning System) technology your car will know where the other vehicles are, additionally other vehicles will know where you are too – whether it is in blind spots, stopped ahead on the highway but hidden from view, around a blind corner or blocked by other vehicles. The vehicles can anticipate and react to changing driving situations and then instantly warn the drivers with chimes, visual icons and seat vibrations. If the driver doesn't respond to the alerts, the car can bring itself to a safe stop, avoiding a collision. A number of technology based systems have evolved to support transportation operations, traffic management, traveler information, fleet management, and incident control. These include:

- Automated Traffic Signal Systems
- Commercial Vehicle Operations (CVO)
- Freeway Management
- Traveler Information
- Remote Weather Information Systems
- Incident Management
- Special Events
- Parking Space locater in Cities.
- Presence of obstacles on road.
- Emergency Braking of a preceding vehicle.
- Information about Blind Crossing, School proximity, Railway crossing etc
- Entries to Highways.

- High Speed Internet Access.
- Nearest Petrol Pump, Workshop etc
- Electronic Toll Collection.

To encourage the development of V2V, the Federal Communications Commission has cleared the 5.9-gigahertz band for dedicated short-range communications (DSRC) among cars, other cars, and roadside transceivers. Even now General Motors had made DSRC-equipped Cadillac CTS that stops itself to avoid accidents. Its enhanced stability-control system predicts where it's headed like, into the rear end of another DSRC car stopped in the middle of the road and prompts the onboard computer to apply the brakes without any input from the driver.

3 Vehicular Communication

3.1 Radio Bands Used in Inter-Vehicle Communication

This section[3] discusses the different frequency bands that can be used in IVC. Bluetooth and Ultra-Wideband (UWB) technologies are explored in some detail. It is possible for communicating vehicles to use both infrared and radio waves. VHF and microwaves are a type of broadcast communication while infrared and millimeter waves are a type of directional communication. Microwaves are used most often. For instance, 75 MHz is allotted in the 5.9 GHz band for dedicated short range communication (DSRC). It is possible to use Bluetooth, which operates in the 2.4 GHz industry, science, and medicine (ISM) band, to set up the communication between two vehicles. It is reliable up to a speed of 80 km/h and range of 80 m. However, it can take up to 3 seconds to establish the communication. Also, since Bluetooth requires a master and slave setup, the master could potentially refuse a communication request. In addition, the master may already be communicating with another slave, which would lower the possible communication rate. An alternative to Bluetooth is a new radio frequency technique called UWB. Because of t he wideband nature of the signal, UWB has been used in radar applications. The Federal Communication Commission (FCC) refers to UWB technology as having high values of fractional bandwidth (¿ 0.25). The main advantages of UWB technology are its high data rate, low cost, and immunity to interference. On the other hand, it could possibly interfere with other existing radio services, for instance, the Global Positioning

System (GPS). The fact that UWB could potentially interfere with communication sources is a technical problem that must be solved before it could be used in IVC systems. Also, there is a concern that UWB's radio coverage could extend to uninvolved vehicles, which could generate false or irrelevant information.

3.2 Overview of Different Vehicular Communications

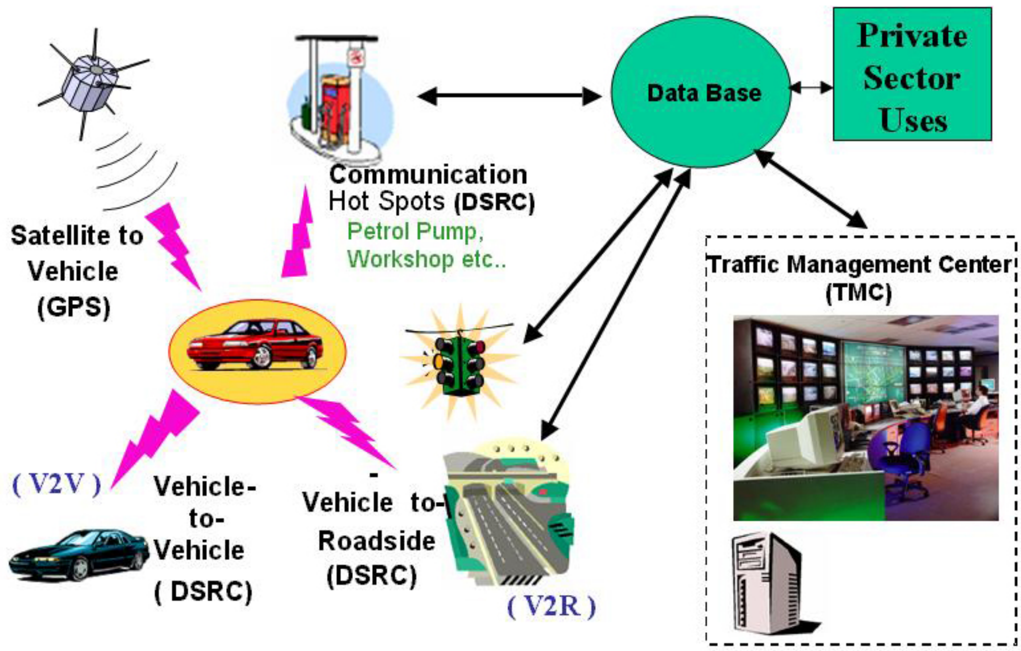

Figure 3.1: Overview of Different Vehicular Comm.

In-vehicle computing systems allow the coverage of monitoring systems to extend beyond the extent of infrastructure-based sensors, e.g., roadside cameras that are expensive to deploy and maintain. Subject to privacy considerations, in-vehicle sensors offer the potential for much more detailed, accurate information (e.g., on-road vehicle activity and emissions) than would otherwise be possible, enabling new ways to improve and optimize the transportation system as well as support a variety of commercial applications. In-vehicle computing systems facilitate the customization of information services to the needs and characteristics of individual travelers. Cooperation between vehicles can reduce the end cost of user services. Possible applications designed to benefit from these in-vehicle computing systems can be generally classified as safety and non-safety applications. Safety applications include, e.g., collision avoidance and cooperative driving. Non-safety applications include traffic information propagation, toll service, Internet access, tourist information, cooperative gaming and entertainment, etc. A V2V network consists of instrumented vehicles equipped with on-board computing and wireless communication devices, a GPS device enabling the vehicle to track its spatial and temporal trajectory, a pre-stored digital map, and optional sensors for reporting crashes, engine operating parameters, etc.

3.3 Dedicated Short Range Communication (DSRC)

Dedicated Short Range Communications (DSRC) is a block of spectrum in the 5.850 to 5.925 GHz band allocated by US FCC (Federal Communication Commission) to enhance the safety and the productivity of the transportation system with regard to ITS. ASTM (American Society for Testing and Materials) standardization committee E17.51 is working on the development of a standard. The drawn MAC schemes are mostly following the IEEE 802.11 MAC, and the greater part is deal with the physical layer in OSI. DSRC is a medium range communication service intended to support both Public Safety and licensed Private operations over roadside-to-vehicle and vehicle-to-vehicle communication channels. DSRC complements cellular communications by providing very high data transfer rates in circumstances where minimizing latency in the communication link and isolating relatively small communication zones are important. And Figure 3.3 shows the DSRC spectrum allocation in 5.9 GHz permitted by FCC in 1999. There are three types of channels in plan, V2V channel, control channel, and V2R channel. To cater to the emerging wireless communication needs with regard to vehicles, in July 2003 ASTM and IEEE adopted the Dedicated Short Range Communication (DSRC) standard (ASTM E 2213-03) [17]. The aim of this standard is to provide wireless communications capabilities for transportation applications within a 1000m range at typical highway speeds. It provides seven channels at the 5.9 GHz licensed band for ITS applications, with different channels designated for different applications, including one specifically reserved for vehicle-to-vehicle communications. The ITS safety applications that could leverage the new DSRC standard include any system that can be enhanced by allowing information to flow between vehicles and between vehicles and roadside infrastructure.

IEEE P1609 Working Group is proposing DSRC as IEEE 802.11p standard. IEEE 802.11p is a standard in the IEEE 802.11 family. IEEE 802.11p also referred to as Wireless Access for the Vehicular Environment (WAVE) defines enhancements to 802.11 required to support Intelligent Transportation Systems (ITS) applications. DSRC is based on IEEE 802.11a.

Bandwidth	75MHz (5.850 5.925GHz)
Modulation	QPSK OFDM
Channels	7 channels
Data Rate	1-54Mbps
Max Range	1000m
Min. Separation	10m

Table 3.1: DSRC Specifications

The extension of the 802.11 MAC layer for DSRC is currently under the IEEE Project P1609.4. The protocol architecture of DSRC is given in Fig 4

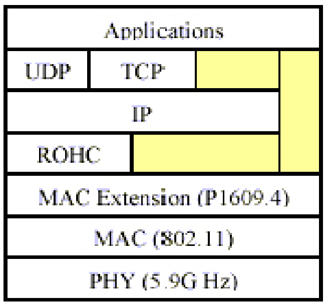

Figure 3.2: DSRC Protocol Architecture

The DSRC standard supports vehicles with an on-board device (OBD) to communicate with a roadside unit (RSU), or other traveling vehicles. FCC provides several examples of DSRC applications as given in the Next generation Vehicular Scenario. We classify these applications into unicast (one sender and one receiver) vs. broadcast (one sender and many receivers) and RSU-to-Vehicle (R2V) vs. Vehicle-to-Vehicle (V2V) as shown in Table 3.2.

3.3.1 DSRC Applications

1. Public safety: to reduce traffic accidents[5]
2. Traffic management: to improve the flow of traffic, reducing congestion
3. Travelers Information Support: to provide a great variety of travel-related timely information, such as electronic maps, and road and weather information

	Unicast	**Broadcast**
R2V	Toll payment, and road side inspection	Safety message,road service, and travel information
V2V	Data sharing,paging, and VoIP	emergency and service vehicles

Table 3.2: Different DSRC Appl.

4. Entertainment/rich media content delivery: Internet access, infotainment (news, sports, movies, etc.) on demand. Three stages in developing DSRC devices and their respective timeframes were identified as follows:

Early adopter device: largely self-contained, minimal interface requirements (for 2003-2005):

- Largely self-contained
- Aftermarket
- Vehicle-powered (a radar detector)
- One front-end
- Moderate power capability
- No network interface
- Minimal driver display (probably separated)

Second-generation device: good feature set without high-cost components/features (for 2007-2008)

- Built-in and aftermarket versions
- Vehicle-powered
- One or two front-ends
- Moderate power capability
- Possible network interface

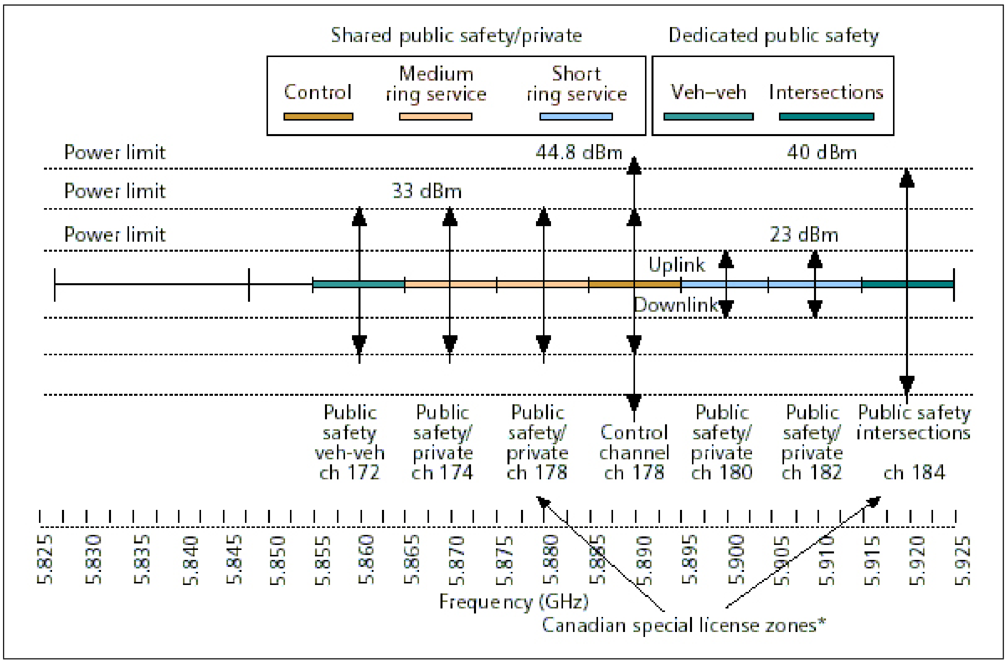

Figure 3.3: 5.9 GHz DSRC band plan with 10 MHz channels and power limit.

- Minimal driver display

Full-blown do-it-all device: 2010

- Built into vehicle
- Vehicle-powered
- Dual front-ends
- High power capability
- High-capability network interface
- Driver interface via network devices

The first-generation device (20032005) only supports very few DSRC applications (other than direct v2v communications) due to the lack of mature MAC and network layer techniques suited for this environment and tailored to the intended applications. Nonetheless, the development of a robust and efficient network will be central to third-generation DSRC devices.

In general, DSRC applications should meet the following requirements[18]:

1. **Low Latency:** Real-time information should be received by traveling vehicles or RSU with low or minimum latency. If the latency is too long, the vehicle may be out of the RF range before the communication is complete.

2. **High mobility:** Study has shown that signal-to-noise ratio goes up and throughput goes down as traveling speed increases . As a result, applications in a fixed wireless environment may not work properly in a mobile environment. We need to consider the factor of high mobility in DSRC application development.

3. **High reliability:** Information from emergency vehicle or RSU has impact on public safety, so their reception by the traveling vehicle should be guaranteed.

4 Application Challenges

Even though V2V communication may be beneficial, wireless communication is typically unreliable. Many factors, for example, channel fading, packet collisions, and communication obstacles, can prevent messages from being correctly delivered in time. In addition, ad hoc networks formed by nearby vehicles are quite different from traditional ad hoc networks due to high mobility of vehicles. Using V2V communication, when a vehicle on the road acts abnormally, e.g., deceleration exceeding a certain threshold, dramatic change of moving direction, major mechanical failure, etc., it becomes an abnormal vehicle(AV). An AV actively generates Emergency Warning Messages (EWMs), which include the geographical location, speed, acceleration and moving direction of the AV, to warn other surrounding vehicles. A receiver of the warning messages can then determine the relevancy to the emergency based on the relative motion between the AV and itself.

4.1 Challenge 1: Stringent delay requirements immediately after the emergency

Over a short period immediately after an emergency event, the faster the warning is delivered to the endangered vehicles, the more likely accidents can be avoided. We define EWM delivery delay from an AV A to a vehicle V as the elapsed duration from the time the emergency occurs at A to the time the first corresponding EWM message is successfully received by V. Since a vehicle moving at the speed of 80 miles/hour can cross more than one meter in 30ms, the EWM delivery delay for each affected vehicle should be in the order of milliseconds.

However, the link qualities in V2V communications can be very bad due to multi path fading, shadowing, and Doppler shifts caused by the high mobility of vehicles. The performance of a wireless LAN in different vehicular traffic and mobility scenarios is assessed, which shows that the deterioration in signal quality increases with the relative and average velocities of the vehicles using 802.11b. Besides unreliable wireless links, packet collisions caused by MAC layer can also contribute to the loss of EWMs.

Moreover, in an abnormal situation, all vehicles close to the AV may be potentially endangered and they all should receive the timely emergency warning. But the group of endangered vehicles can change quickly due to high mobility of vehicles. For example, in Figure 4.1, at the time of emergency event at vehicle A, the nearby vehicles N1, N2, N3, N4 and N5 are put in potential danger. Very soon, vehicles N5 and N1 may pass A and should no longer be interested in the emergency warning. Meanwhile, vehicles N6, N7 and N8 can get closer and closer to A and should be informed about the abnormal situation.

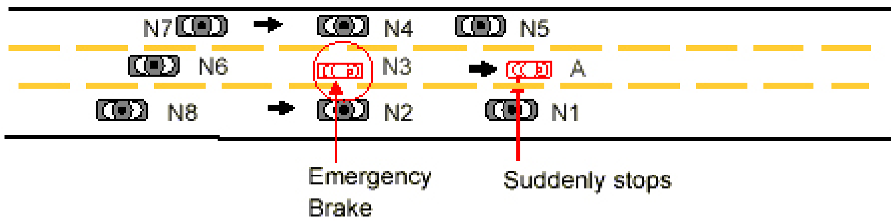

Figure 4.1: N3 reacts to the sudden stop of vehicle A with emergency brake

Both the unreliable nature of wireless communication and the fast changing group of affected vehicles create challenges for satisfying the stringent EWM delivery delay constraint in cooperative collision warning.

4.2 Challenge 2: Support of multiple co-existing AVs over a longer period

After an emergency event happens, the AV can stay in the abnormal state for a period of time. For example, if a vehicle stops in the middle of a highway due to mechanical failure, it remains hazardous to any approaching vehicles, and hence, remains an abnormal vehicle until it is removed off the road.

Furthermore, emergency road situations frequently have chain effects. When a leading vehicle applies an emergency brake, it is probable that vehicles behind it will react by also decelerating suddenly.

We define co-existing AVs as all the AVs whose existences overlap in time and whose transmissions may interfere with each other. Due to the fact that an AV can exist for a relatively long period and because of the chain effect of emergency events, many co-existing AVs can be present.

Therefore, in addition to satisfying stringent delivery delay requirements of EWMs at the time of emergency events, the vehicular collision warning communication protocol has to support a large number of co-existing AVs over a more extended period of time.

4.3 Challenge 3: Differentiation of emergency events and elimination of redundant EWMs

Emergency events from AVs following different lanes/trajectories usually have different impact on surrounding vehicles, hence, should be differentiated from each other. As the example in Figure 4.2 shows, vehicle A is out of control and its trajectory crosses multiple lanes. In such an abnormal situation, N1 and N3 may both react with emergency braking and it is important for both N1 and N3 to give warnings to their trailing vehicles, respectively. At the same time, since the trajectory of vehicle A does not follow any given lane and it may harm vehicle in the near future, vehicle A needs to give its own emergency warning as well. In this particular example, three different emergency events are associated with three different moving vehicles.

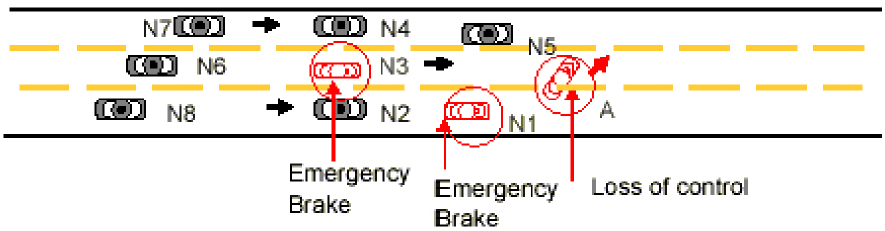

Figure 4.2: Multiple AVs following different trajectories

On the other hand, multiple AVs may react to a same emergency event and impose similar danger to the approaching vehicles. For example, in Figure 4.1, vehicle A suddenly stops in the middle of road. In reacting to the sudden stop of A, vehicle N3 brakes abruptly and stops behind A as well. From the viewpoint of vehicle A, vehicle N3 shields it from all vehicles behind.

In such a case, there is no need for A to continue sending redundant EWMs some time after the emergency for several reasons: first, channel bandwidth would be consumed by unnecessary warning messages; and second, as more senders contend for a common channel, the delays of useful warning messages are likely to increase.

In real life, various reactions from drivers can happen. In the example of Figure 4.1, EWMs from A is redundant as long as N3 stays behind it and sends EWMs. Later on, the driver of N3 may change lane and drive away. When this happens, EWMs from A becomes necessary again if A remains stopped in the middle of the road. Therefore, the design of collision warning communication protocol needs to both take advantage of traffic patterns, and be robust to complicated road situations and driver behaviors.

5 Vehicular Collision Warning Communication (VCWC) Protocol Proposal

A vehicle can become an abnormal vehicle (AV) due to its own mechanical failure or due to unexpected road hazards. A vehicle can also become an AV by reacting to other AVs nearby. Once an AV resumes it regular movement, the vehicle is said no longer an AV and it returns back to the normal state. In general, the abnormal behavior of a vehicle can be detected using various sensors within the vehicle. Exactly how normal and abnormal statuses of vehicles are detected is beyond the scope of this paper. We assume that a vehicle controller can automatically monitor the vehicle dynamics and activate the collision warning communication module when it enters an abnormal state. A vehicle that receives the EWMs can verify the relevancy to the emergency event based on its relative motion to the AV, and give audio or visual warnings/advice to the driver.

Each message used in VCWC protocol is intended for a group of receivers, and the group of intended receivers changes fast due to high mobility of vehicles, which necessitate the message transmissions using broadcast instead of unicast. To ensure reliable delivery of emergency warnings over unreliable wireless channel, EWMs need to be repeatedly transmitted.

Conventionally, to achieve network stability, congestion control has been used to adjust the transmission rate based on the channel feedback. If a packet successful goes through, transmission rate is increased; while the rate is decreased if a packet gets lost.

Unlike conventional congestion control, here, there is no channel feedback available for the rate adjustment of EWMs due to the broadcast nature of EWM transmissions. Instead, we identify more application-specific properties to help EWM congestion control, which consists of the EWM transmission rate adjustment algorithm and the state transition mechanism for AVs.

This paper also focuses on Congestion Control Policies; the proposed VCWC protocol also includes emergency warning dissemination methods that make use of both natural response of human drivers and EWM message forwarding, and a message differentiation mechanism that enables cooperative vehicular collision warning application to share a common channel with other non-safety related applications.

5.1 Assumptions

We first clarify related assumptions we have made for each vehicle participating in the cooperating collision warning.

- Such a vehicle is able to obtain its own geographical location, and determine its relative position on the road (e.g., the road lane it is in). One possibility is that, the vehicle is equipped with a Global Position System (GPS) or Differential Global Position System (DGPS) receiver to obtain its geographical position, and it may be equipped with a digital map to determine which lane it is in.

- Such a vehicle is equipped with at least one wireless transceiver, and the vehicular ad hoc networks are composed of vehicles equipped with wireless transceivers.

- As suggested by DSRC, the transmission range of safety related vehicle-to-vehicle messages is assumed to be 300m (in early stage), and channel contention is resolved using IEEE 802.11 DCF based multi-access control.

5.2 State Transitions of AVs

The objective of the state transition mechanism is to ensure EWM coverage for the endangered regions and to eliminate redundant EWMs, while incurring little control overhead.

Each AV may be in one of three states, initial AV, *non-flagger* AV and *flagger* AV. When an emergency event occurs to a vehicle, the vehicle becomes an AV and enters the initial AV state, transmitting EWMs following the Rate Decreasing Algorithm described in Section 4.2 of [2]. An initial AV can become a *non-flagger* AV, refraining from sending EWMs contingent on some conditions to eliminate redundant EWMs. In some road situations, it is necessary for a *non-flagger* AV to become a *flagger* AV, resuming EWM transmissions at the minimum required rate.

1. At least T_{alert} duration has elapsed since the time when the vehicle became an initial AV. As EWMs have been repeatedly transmitted over T_{alert} duration, by then, the vehicles having been close to the AV should have received the emergency warning with high probability.

2. EWMs from one of the “followers” of the initial AV are being overheard; here, we define vehicle X as a “followers” of vehicle Y, if X is located behind Y in the same lane and any vehicle endangered by Y may also be endangered by X.

In the example shown in Figure 5.1, abnormal vehicle A malfunctions and stops. Upon receiving the EWMs from vehicle A, the trailing vehicle N3 reacts and stops as well. As N3 responds with abrupt action, it also becomes an AV and begins to send EWM messages. Since A and N3 impose similar danger to any vehicle approaching this region, using above state transition rule, A enters the *non-flagger* AV state when it receives EWMs from N3, and T_{alert} duration has elapsed since the initial occurrence of the emergency event at vehicle A . On the other hand, without overhearing any EWMs from other AVs behind, N3 is not eligible to be a *non-flagger*. Hence, it remains as an initial AV and keeps on sending EWM messages. With EWMs from N3, approaching vehicles can get sufficient warning to enable their drivers to respond appropriately.

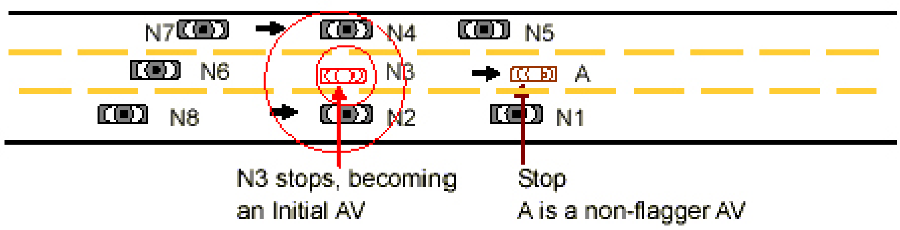

Figure 5.1: N3 sends EWM and A becomes a non-flagger AV

Transitions between non-flagger AV state and flagger AV state: An AV in the *non-flagger* AV state sets a timer for a Flagger Timeout (FT) duration. If it does not receive any EWMs from its followers when the FT timer expires, the *non-flagger* AV changes its state to *flagger* AV. Otherwise; it simply resets the FT timer and repeats above procedures. If a *flagger* AV receives EWMs from one of its followers, it will relinquish its *flagger* responsibility, becoming a *non flagger* AV.

A *flagger* AV transmits EWMs at the minimum rate λ_{min} since a vehicle can only become a flagger AV some time after the emergency. Observe that, at the time when an emergency occurs, the emergency warning needs to be delivered to all surrounding vehicles as soon as possible because the endangered vehicles can be very close to the AV. After a while, however, the nearby vehicles should have received the emergency warnings with high probability. What matters then is to give emergency warnings to approaching vehicles that just enter the transmission range of the AV. Therefore, the value of λ_{min} is mainly determined by the radio transmission range, maximum speed, deceleration capability of vehicles and channel conditions. If radio transmission range is large enough, an approaching vehicle can tolerate a relatively long delivery delay. For example, in Figure 5.1, N6 enters the transmission range of A some time after the emergency event. If we assume that the transmission range is 300 meters,(in early cases), then one or two second delay in receiving the emergency warning for N6 should not cause much negative impact.

Continuing our example in Figure 5.1: at this point of time, N3 is an initial AV and A is a *non-flagger* AV (Figure 5.1). After a while, N3 finds a traffic gap on the next lane and drives away. As vehicle A can no longer hear EWMs from N3, A changes its state to a *flagger* AV after its FT timer expires, and begins to send EWMs again, as shown in Figure 5.2.

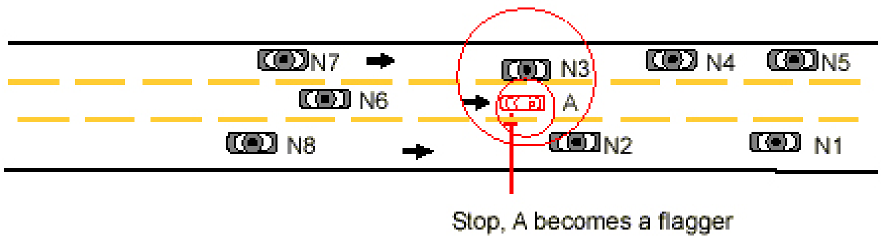

Figure 5.2: N3 drives away; A identifies itself as a flagger

The situation involving several reacting AVs is illustrated in Figure 5.3. The last AV in a "piled up" lane, vehicle N11 in this example, always remains as an initial AV and sends EWMs (as it is not eligible to be a *non-flagger* AV without receiving EWMs from a follower). Additionally, vehicle N9 identifies itself as a *flagger* as it cannot hear EWMs from N11. Similarly, vehicle A also identifies itself as a *flagger* since it is out of the transmission range of N11 and N9.

Because an AV starts to generate its own EWMs if no EWMs from its followers are overheard when its FT timer expires, the longest time period during which no EWMs are transmitted to a vehicle since it enters the transmission range of an AV is 2FT. By choosing an appropriate value for FT based on the radio transmission range, maximum speed, deceleration capability of vehicles, channel conditions and the value of λ_{min} , we can ensure that, with very high probability, all approaching vehicles can receive emergency warning in time to react to potential danger ahead.

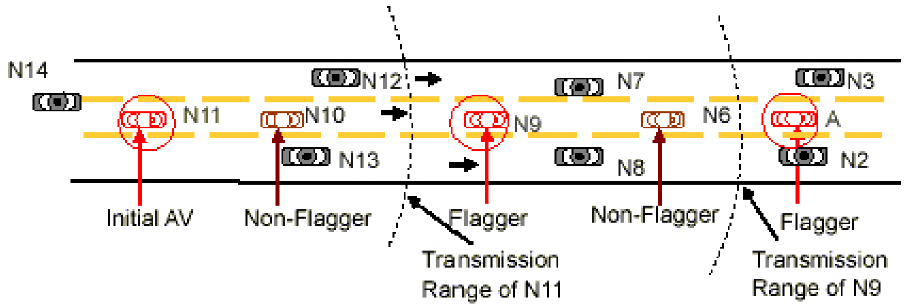

Figure 5.3: Full coverage of endangered region

Implementing above state transition mechanism does not incur any additional control messages beyond the EWMs already being sent, and the mechanism is robust to dynamic road scenarios and wireless link variations. If the channel is good, there will be only one AV sending EWMs per transmission range; if the channel condition is poor, EWMs from existing *flaggers* may get lost and more *flaggers* than necessary can appear from time to time. But clearly, the correctness of the above algorithm is not affected, which ensures that a vehicle entering the transmission range of an AV will always be covered by EWMs transmitted by *flagger* AVs or initial AVs. The proposed VCWC protocol is able to support many co-existing AVs using the rate decreasing algorithm.

6 Related Works

In 1992, IVHS America (the Intelligent Vehicle-Highway Society of America) brought its industry sectors - private industry, academia, and government - together with the US DOT and collaborated on the development of a Strategic Plan for IVHS in the United States. The plan clearly noted "as development proceeds, there will be increasing interaction among traffic management, traveler information, and vehicle control systems." In 1995, the newly-renamed ITS America again collaborated with the US DOT on the development of a National ITS Program Plan that clearly visualized intersection collision avoidance applications that "may involve infrastructure-to-vehicle and/or vehicle-to vehicle communications."

Six years later in 2001, ITS America and the US DOT came together yet again, and began to lay the groundwork for the future in the development of a new strategic document, the National ITS Program Plan: A Ten-Year Vision. This Plan outlined an enabling path to collision avoidance "through the use of dedicated short-range communications to support infrastructure-vehicle and vehicle-vehicle communications," particularly in the 5.9GHz band allocated by the Federal Communications Commission (at the request of ITS America) for ITS safety applications.

ITS Program recently re-organized into many areas; some of them are Integrated Vehicle Based Safety Systems, Cooperative Intersection Collision Avoidance Systems, Vehicle Infrastructure Integration (VII) etc... Each has its own goal, vision and deployment method. Their goals are respectively, all new vehicles equipped with advanced driver assistance systems to help drivers avoid the most common types of deadly crashes; Achieve deployment of intersection collision avoidance systems at 15% of the most hazardous signalized intersections nationally, with in-vehicle support in 50% of the vehicle fleet by 2015. Also nationwide deployment of a communications infrastructure on roadways and in all production vehicles to enable a number of key safety and operational services (ie VII). For that, the vehicle manufacturers would install the technology in all new vehicles, beginning at a particular model year; at the same time, federal/state/local transportation agencies would facilitate installation of a roadside communications infrastructure. Again the assumption is that decisions about full-scale deployment in both the vehicles and the infrastructure will need to be made in the 2008/9 timeframe.

To determine the feasibility and an implementation strategy, a three-party consortium has been formed consisting of the seven vehicle manufacturers, AASHTO (American Association of State Highway and Transportation Officials) ten State departments of transportation and the USDOT.

There are many projects related to communication networks among road-users. FleetNet and CarTALK 2000 are some of them. FleetNet is a German project for Internet on the road and is about an ad-hoc radio network for inter-vehicle communications. Among the participants, we find Siemens, NEC, Bosch, DaimlerChrysler, and three German universities. They plan to use the UTRA TDD radio hardware. UTRA TDD is one of the 3G systems defined by ITU. From the information available about the project, it appears that the FleetNet system (like many others) is more about connecting vehicles to internet and not that much to avoid traffic accidents, which will not be possible by using UTRA TDD.

CarTALK 2000 is an EU-IST funded project in the fifth framework program, started August 2001 and funded for three years. It is focusing on new driver assistance systems which are based upon inter-vehicle communication. The main objectives are the development of co-operative driver assistance systems and the development of a self-organizing ad-hoc radio network as a communication basis with the aim of preparing a future standard.

The European Commission is funding several projects under the so-called eSafety initiative launched in 2002 in order to halve the number of road fatalities by 2010 (in 2005 40,000 persons were killed and 1.8 million severely injured in the sole European Union). Another incentive is the desire to limit traffic congestion and thus to optimize road density and the number of people in a given vehicle. Yet another one is consumption, which is indeed a function of the traffic congestion and advanced itinerary planning. All of these are the motivations behind Intelligent Car, one of the European Information Society 2010 (i2010) Flagship initiatives adopted in February 2005.

The Car2Car Communication Consortium (C2C-CC) is a non-profit organisation initiated by European vehicle manufacturers, which is open for suppliers, research organisations and other partners. The Car2Car Communication Consortium is dedicated to the objective of further increasing road traffic safety and efficiency by means of inter-vehicle communications. The mission and the objectives of the Car2Car Communication Consortium are to create and establish an open European industry standard for Car2Car communication systems based on wireless LAN components and to guarantee European-wide inter-vehicle operability,to enable the development of active safety applications by specifying, prototyping and demonstrating the Car2Car system, to promote the allocation of a royalty free European wide exclusive frequency band for Car2Car applications etc...

7 Conclusion

This paper shows an Overview of different vehicular communication with regard to Intelligent Transportation System, also the Vehicle to Vehicle (V2V) communication using DSRC Standard is described. This paper also discussed some of the application challenges and proposes a new protocol which provides congestion control polices. This protocol defines congestion control policies for emergency warning messages so that a low emergency warning message delivery delay can be achieved and a large number of co-existing abnormal vehicles can be supported. It also introduces a method to eliminate redundant emergency warning messages, exploiting the natural chain effect of emergency events.

ROAD SAFETY Benefits for all actors

Drivers: will drive vehicles equipped with more robust driving assistance systems thanks to dynamic information about the traffic, the road and the environmental conditions from the vehicle net and from the infrastructure.

Car makers: will open new market opportunities offering on the market new functions for safer vehicles at sustainable costs as the 'intelligence' will be distributed. The level of complexity of vehicles will be decreased, compared to autonomous solutions.

Suppliers: will meet the challenge of new market opportunities being ready to offer fully developed technical solutions and actively driving the evolution in terms of concept generation, and standardisation.

Road operators and public authorities: will improve road safety on motorways and urban roads via a combination of infrastructure and vehicle systems that will collect and transmit in real time traffic/weather and accident information to all road users and to traffic information centers.

Wireless in-vehicle network technologies and protocols have the potential to support many new and innovative applications. These applications are based on intra-vehicle, vehicle-to-vehicle, and vehicle-to-roadside networking of in-vehicle systems and devices. These technologies can greatly enhance the infotainment, telematics, safety, comfort, and convenience value of new vehicles. A new era is arriving where vehicles will communicate with each

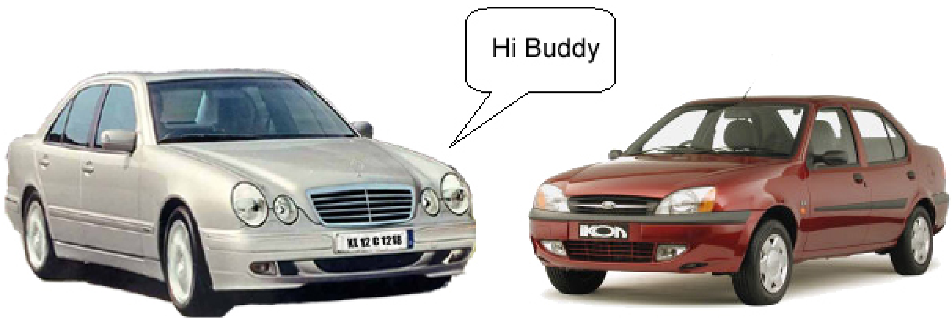

Figure 7.1: In the mere future,we can expect cars talking each other

other, the devices within them, and also with the world; making the next generation of vehicles into communication hubs.

•

References

[1] S Biswas, “Vehicle-to-Vehicle Wireless Communication Protocols for Enhancing Highway Traffic Safety”,*Communications Magazine, IEEE Publication* Date: Jan. 2006 Volume: 44, Issue: 1 page(s):74- 82

[2] X. Yang et al., “A Vehicle-to-Vehicle Communication Protocol for Cooperative Collision Warning”, *Proc. 1st Annual Intl. Conf. Mobile and Ubiquitous Syst: Networking and Services*, 2004.

[3] G.S Bickel, “Inter/Intra-Vehicle Wireless Communication” also available at `http://userfs.cec.wustl.edu/~gsb1/index.html`

[4] Q. Xu, R. Sengupta, and D. Jiang, “Design and Analysis of Highway Safety Communication Protocol in 5.9 GHz Dedicated Short-Range Communication Spectrum”, *Proc. IEEE VTC*, vol. 57, no. 4, 2003, pp. 245155.

[5] J. Zhu and S. Roy, “MAC for Dedicated Short Range Communications in Intelligent Transport Systems”, *IEEE Commun. Mag.*, vol. 41, no. 12, 2003.

[6] C.Bettstetter “Toward Internet-Based Car Communications: On Some System Architecture And Protocol Aspects” *Inst. of Comm. Networks* TUM, Germany

[7] A.Svensson, *Fellow, IEEE*, “A Communication Network for Safe Traffic and Efficient Transportation” Dept. of Sig. & Sys, Chalmers Uni.of Tech,Swedan

[8] L.Iftode, C. Borcea, N. Ravi, T .Nadeem “Exploring the Design and Implementation of Vehicular Networked Systems”

[9] MD Dikaiakos, S. Iqbal, T. Nadeem, L. Iftode “VITP: An Information Transfer Protocol for Vehicular Computing”

[10] Dashtinezhad, T.Nadeem, C.Borcea, B.Dorohonceanu "Traffic View: A Driver Assistant Device for Traffic Monitoring based on Car-to-Car Communication"

[11] H Wu, "Analysis and Design of Vehicular Networks" ,Georgia Inst. of Tech, Oct. 30,2004

[12] J.-H. Li, C.-H. Chang, and Y.-H. Chan "MAC (Media Access Control) Design and Implementation of DSRC (Dedicated Short Range Communication) Systems"

[13] "India's accident record among the worst in the world" Online Edition of newspaper 'Deccan Herald' , Wednesday, February 16, 2005

[14] National Center for Statistics and Analysis, "Traffic Safety Facts 2003," Report DOT HS 809 767, *Natl. Highway Traffic Safety Admin.*, U.S. DOT, Washington, DC, 2004.

[15] C. D. Wang and J. P. Thompson. "Apparatus and method for motion detection and tracking of objects in a region for collision avoidance utilizing a real-time adaptive probabilistic neural network", 1997. US.Patent No. 5,613,039.

[16] M. Green. "How Long Does It Take to Stop?" *Methodological Analysis of Driver Perception-Brake Times. Transportation Human Factors*, 2(3):195-216, 2000.

[17] ASTM E2213-03, "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," ASTM Intl., July 2003.

[18] James T. Yu, "Requirements Analysis of IP and MAC Protocols for Dedicated Short Range Communications (DSRC)", School of Comp. Sc., De Paul University.

[19] `http://www.car-to-car.org`

[20] `http://www.leearmstrong.com/DSRC/DSRCHomeset.htm`

Appendix

1 Abbreviation

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
AV	Abnormal Vehicle
DCF	Distributed Coordination Function
DGPS	Differential GPS
DSRC	Dedicated Short Range Communication
ETC	Electronic Toll Collection
EWM	Emergency Warning Message.
FCC	Federal Communications Commission
GPS	Global Positioning System
ISM	Industry, Science, and Medicine
ITS	Intelligent Transportation Systems
ITU	International Telecommunication Union
IVC	Inter-Vehicle Communication
MAC	Medium Access Control
OBD	On-Board Device
OFDM	Orthogonal Frequency division multiplexing
OSI	Open Systems Interconnection
RSU	Road Side Unit
TDD	Time Division Duplex
US DOT	United States Department of Transportation
UTRA	Universal Terrestrial Radio Access
UWB	Ultra-Wide Band
V2R	Vehicle to Roadside
V2V	Vehicle to Vehicle
VCWC	Vehicular Collision Warning Communication
WAVE	Wireless Access in the Vehicular Environment