Vehicle to Vehicle Wireless Communication Protocol

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Abstract: ***In vehicle to vehicle wireless communication protocol 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. And in vehicle to vehicle wireless communication protocol, 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 analyzed.***

Keywords: Vehicle to vehicle communication protocol, abnormal vehicle, Dedicated Short Range Communication (DSRC)

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 .Every year in the United States, about six million traffic accidents occur due to automobile crashes. In 2003 alone, these accidents accounted for $230billion in damaged property, 2,889,000 nonfatal injuries, and 42,643 deaths. While different factors contribute to vehicle crashes, such as vehicle mechanical problems and bad weather, driver behavior is considered to bethe 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 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.

2. Existing System

Vehicular Communication

2.1 Radio Bands Used in Inter-Vehicle Communication

In radio bands used in inter-vehicle communication, 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 the 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.

2.2 Overview of Different Vehicular Communications

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.

2.3 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 2.2.3 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.

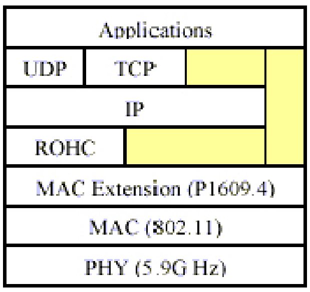


Figure 2.2.3: DSRC Protocol Architecture

3. Proposed System

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.

4. Future Scope

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.

5. Performance Evaluation

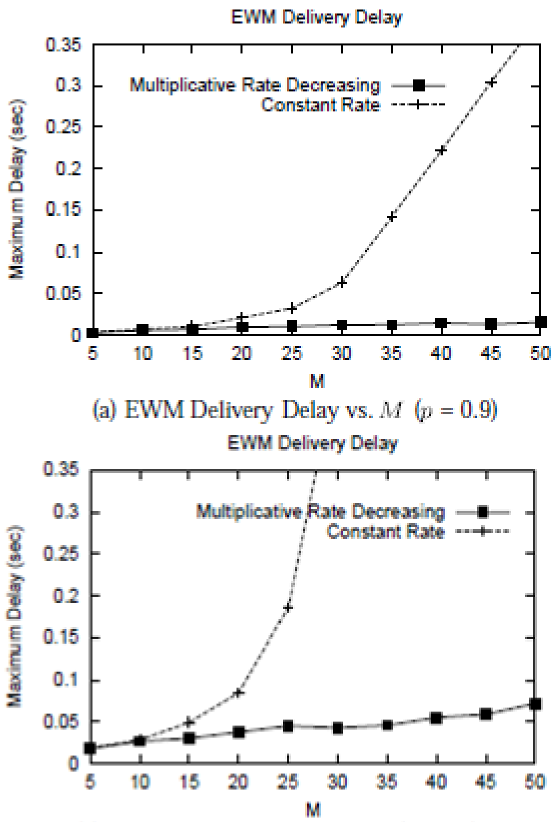
The proposed VCWC protocol is implemented using ns-2 network simulator. The channel physical characteristics follow the specification of 802.11b, with channel bit rate of 11 Mbps. The radio transmission range is set to 300 meters, as suggested by DSRC .

The underlying MAC protocol is based on IEEE 802.11 DCF, with the added functions of service differentiation. In our implementation, whenever an AV has a backlogged EWM, it raises an out-of-band busy tone signal, which can be sensed by vehicles located within two hop distance. Vehicles with lower priority messages defer their channel access whenever the busy tone signal is sensed.

From empirical data, we set the minimum EWM transmission rate ƛmin to 10 messages/sec, the flagger timeout duration *FT* to 0.5 seconds and the minimum EWM transmission duration *Talert* for an *initial AV* to 450 milliseconds in the simulations. Using simulation results, we also identified in that the combination L=0.5 and ƛ0=100 messages/sec is a proper choice for the multiplicative rate decreasing algorithm.

5.1 EWM Delivery Delay

As we discussed the related works, prior related work has focused on different issues from vehicle to vehicle wireless communication protocol, which makes direct performance comparison difficult. Below, the simulation results for EWM delivery delay achieved by the multiplicative rate decreasing algorithm used by the proposed VCWC protocol, compared with the constant rate algorithm that transmits EWMs at the rate of ƛ0 are presented.



(a) EWM Delivery Delay vs. M ($p = 0.9$)

(b) EWM Delivery Delay vs. M ($p = 0.5$)

Figure 5.1: EWM Delivery Delay Comparison between Multiplicative Rate Decreasing & Constant Rate Algorithm

The simulated scenario includes a road segment of 300 meters, with 5 lanes and 10 vehicles distributed on each lane. There are totally 50 vehicles and all of them are within each other's transmission range. The total number of coexisting AVs (M) varies from 5 to 50, where the occurrence rate of new AVs is 5 every 0.1 second. Each AV continuously sends EWMs until the end of the simulation. EWM warning from each AV is required to be delivered to all vehicles within the transmission range (it is up to each individual vehicle that receives the EWM warning to decide whether the EWM warning is relevant or not). The maximum EWM delivery delay among all AV-receiver pairs is measured. Figure 5.1 (a) shows the maximum EWM delivery delay when channel condition is relatively good (p= 0.9), while Figure 5.1(b) presents the results with a poor channel condition (P= 0.5).

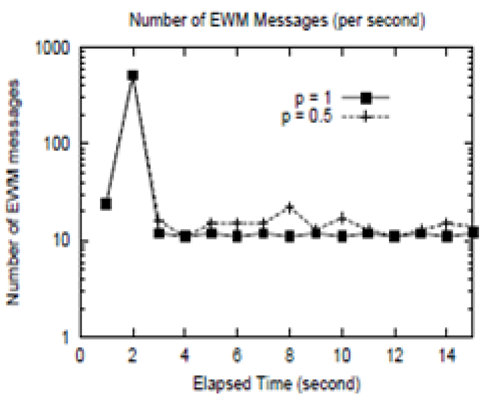
With 5 co-existing AVs, the network offered load resulting from EWM transmissions is low, implying a low message waiting time in the system. In addition, the degradation of retransmission delay using the proposed rate decreasing algorithm is quite insignificant, as we discussed in Section rate decreasing algorithm for EWMs. Hence, both the multiplicative rate decreasing algorithm and the constant rate algorithm achieve low EWM delivery delay when (is small, as shown in Figures 5.1 (a) and (b). With the increase of co-existing AVs, however, the offered load using the constant rate algorithm increases rapidly, leading to fast growing message waiting time. Beyond 25 co-existing AVs, the total EWM arrival rate exceeds channel service rate, the system becomes unstable and the message waiting time increases dramatically. On the other hand, the rate decreasing algorithm controls the EWM transmission rate over time. When new AVs join, existing AVs have reduced their EWM transmission rates, leading to moderately increased network load. Consequently, with the increase of co-existing AVs, EWM delivery delay only increases slightly using the rate decreasing algorithm.

Similar results based on the analytical derivation have been presented in EWM delay vs M. We can see that the simulation results in Figure 5.1 agree with our analytical results in FiG: EWM delay vs M on the general trend.

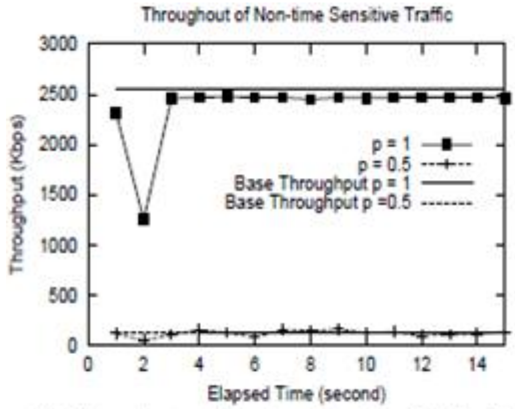
It is possible to decrease the EWM transmission rate used by the constant rate algorithm so that EWM delivery delay increases more slowly with the increase of co-existing AVs. However, due to the increased retransmission delay, it unnecessarily increases the EWM delivery delay when there are only a smaller number of co-existing AVs.

5.2 Elimination of Redundant EWMs

To show the effects of redundant EWM elimination, it is assumed that all AVs impose similar danger to the approaching vehicles. One 600 meter long road lane segment is simulated, and 60 vehicles equipped with wireless transceivers are evenly distributed on the road. Emergency event happens to the leading vehicle as soon as a simulation starts. To simulate the worst-case scenario, we let each trailing vehicle that received EWMs from the leading vehicle react with abrupt deceleration, and eventually stop in the lane. Thus, all trailing vehicles within the transmission range of the leading vehicle become AVs once they begin their reactions. Driver reaction time is randomly chosen over the range from 0.7 seconds to 1.5 seconds. Throughout the simulations, there exist two source stations that have constantly backlogged non-time-sensitive messages with packet size of 512 bytes.



(a) Number of EWMs (Per Second)



(b) Throughput of Non-time Sensitive Traffic (Per Second)

Figure 5.2: Elimination of Redundant EWMs

Figure 5.2(a) illustrates how the total number of EWMs from all AVs changes over time for two channel conditions (p=1 and p=0.5¦), where the number of EWMs is measured over each second. For example, the point at time 1s in Figure 5.2(a) represents the total number of EWMs sent from time 0s to 1s

At time 0s the leading vehicle becomes an AV, and starts to send EWMs. As the driver reaction time ranges from 0.7 seconds to 1.5 seconds, the number of EWMs surges from 1s to 2s when all the trailing vehicles located within the transmission range of the leading vehicle become AVs. Each AV transmits EWMs for at least T alert(450ms) duration, and then is qualified as a *non-flagger AV* if EWMs from a follower are overheard. As evident in Figure 8(a), redundant EWMs are effectively eliminated as the amount of EWMs drops significantly from time 2s to 3s. In the end, with perfect channel condition, only one AV remains transmitting EWMs at the rate of 10 messages/sec. When channel condition is bad, say p=0.5 slightly more EWMs may be transmitted from time to time, as shown in Figure 5.2(a).

The amount of channel bandwidth consumed by EWM messages can be revealed from the throughput loss of nontime- sensitive traffic. The throughput obtained by the nontime- sensitive traffic, which is also measured over each second, is shown in Figure 5.2(b). The curves marked as “base throughput” show the throughput obtained by non-time sensitive traffic when there is no emergency event. Evidently, messages related to vehicular collision warning only consume significant channel bandwidth during a short period after the emergency event. Starting from time 3s, non-time-sensitive traffic suffers very little throughput loss. When channel condition is bad, say p=0.5 the relative throughput loss is even smaller comparing with D-/because the base throughput itself is very low with poor channel condition.

From above simulation results, we conclude that the proposed VCWC protocol can satisfy emergency warning delivery requirements and support a large number of coexisting AVs at the low cost of channel bandwidth.

6. 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

a) **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.
b) **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.
c) **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 standardization.
d) **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 other, the devices within them, and also with the world; making the next generation of vehicles into communication hubs.

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