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Smart Inter-Vehicular Communication System for Saving Human Lives

Sama Qazi[1], Tawseef Naqishbandi[2]

[1]Department of E& C, Islamic University of Science and Technology Awantipora, Kashmir

[2]Department of CSE, Islamic University of Science and Technology Awantipora, Kashmir

Abstract: ***Recent studies have shown that about 60%of road accidents can be reduced if the driver is warned before. Studies in Europe have also shown that warning signals about the road traffic, road topology ahead allows for early braking which resulted in 3.6% crash reduction. Road accidents have become the main cause of mortality in today's world. To avoid this new technologies have come into existence to provide faster & reliable communication between the vehicles. Vehicular Ad hoc networks are emerging as a new class of wireless network spontaneously formed between moving vehicles equipped with wireless interfaces, passengers & pedestrians. Inter vehicle communication is attracting considerable attention from research community. As it will help to increase road safety, reduce traffic congestion and can assist drivers with safety and information.***

Keywords: Inter Vehicle communication, Vehicular Ad hoc Network (VANETs), protocol

1. Introduction

Vehicles represent such a fundamental component in our society that ratio of vehicle-population to human-population in cities is constantly on increase. Now this would have a strong effect on our lives and we now need advanced inter vehicle communication capabilities. Through these new communication capabilities, vehicles will provide several new services to their passengers. A limited but representative list of new services that will be made available by the DSRC/IEEE 802.11p technology includes road vehicle safety, road navigation support, location-related commercials, and networked interactive entertainment. The vehicle infrastructure integration was first launched by the U.S. Department of transportation (USDOT) during the ITS World congress in 2003. Then the vehicle infrastructure Integration consortium was formed in early 2005. IVC has attracted research attention from the transport industry of Japan and US. Within this area there are also a lot of different services that can be provided, and different strategies to implement them. The main goal of IVC is to upgrade on board devices (i.e. GPS, sensors) and thus to extend the horizon of drivers. IVC applications can provide us with Cooperative assistance systems focused on coordinating the vehicles in critical points like junctions with no traffic lights. Communication-based longitudinal control tries to exploit the look-through capability of IVC to reduce accidents and platooning vehicles to increase the capacity of the road, while information and warning functions give support with real-time warning messages to avoid collisions.

Inter-Vehicular Communication can be categorized in two parts; Vehicle to Vehicle Communication (V2V) and Vehicle to Infrastructure (V2I). The two or more vehicles can share information regarding their speed, direction using wireless communication in a V2V communication. If the communication is between a vehicle and an infrastructure then it falls under the realm of Vehicle to Infrastructure (V2I) communication. The vehicles can communicate using a fix infrastructure along the road to access support services like Internet access, inter-vehicle chat, mobile advertising etc.

CarTALK & Fleetnet have looked into the potential of ad-hoc communication between vehicles. An Ad-hoc network allows for communication between vehicles to connect & transmit signals without the need for a base station. Essentially this saves money on implementation costs & increases efficiency in communication between cars. CarTALK researchers have found that a multi hop communication link between cars works well in sending information back upstream. Multi hop communication allows for a broadcasted signal to be "grabbed" by cars upstream & rebroadcasted for cars further upstream to grab the signal & retransmit it. Implementation of multi hop communication allows for information warning signals to be alerted to drivers before they would be visually aware of the situation. This project offers an optimal way to use the roadways. The idea here is that a leading car driven by a human sends information to a group of followers, which repeat exactly the same the driver-pattern conduct of the leading car. This is called 'platooning' of vehicles. Not only does it make a better use of the roadway capacity, but it also saves power as the group pattern becomes aerodynamic. Most of these projects use the standard IEEE 802.11 for communication. But also GSM, UMTS, GPRS protocols are used in some of these projects.

This paper is focused on how the inter-vehicular communication (IVC) can play a significant role in reduction of road accidents. The remainder of the paper is organized as follows: requirements for this system are presented in Section 2. Section 3 presents the proposed architecture. The Vehicular Collision warning communication protocol is given in Section 4. And applications in this area are presented in Section 5 followed by conclusion in Section 6.

2. Smart IVC System Requirements

There are several pressing requirements that the Smart IVC System must meet in order to be considered safe and effectively functional for deployment. Availability, reliability, safety, integrity and security are among the main requirements for IVC systems. However wireless communication is typically unreliable due to packet collisions, channel fading, shadowing and the Doppler shifts caused by the high speed of vehicles. It becomes more challenging to deal with sensor nodes traveling at high speed. The latency requirement can be critical, because of the high speed of the vehicles. Let us consider two vehicles A and B driving at 180 Km/h. Then vehicle A sees an obstacle and decides to break. In this case, IVC systems must support a warning mechanism that warns vehicle B with enough time to stop in time.

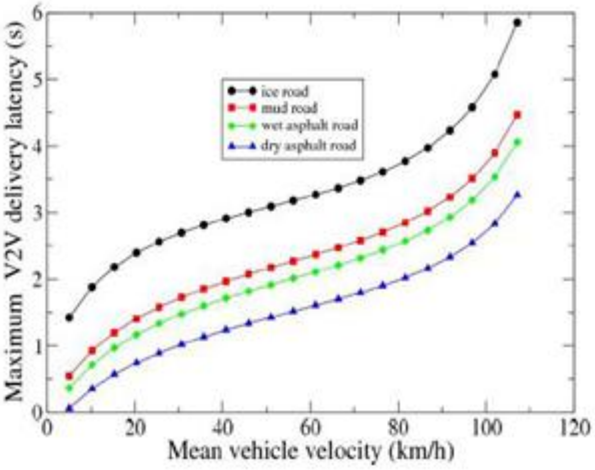

Figure 1: Latency Requirement Graph

It can be seen from the graph in Figure 1, that the latency requirement grows exponentially as the vehicle move faster. Security requirements are also important. A vehicle could transmit false warnings, in order to show up as an emergency vehicle. Also, messages can be used to track a vehicle and get private information about the driver and passengers. Security mechanisms such as authentication, integrity and privacy protection must be supported. The IVC networks must also support scalability. The network can become dense in a very short time, if a lot of vehicles get stuck in a traffic jam.

3. System Architecture

A vehicular network can be deployed by network operators and service providers or through integration between operators, providers and appropriate governmental authority. Recent advances in wireless technologies and emerging trends in ad hoc network scenarios allow a number of deployment architectures for vehicular networks. Such network architectures can be deployed for highway, rural and city environments. Irrespective of the deployment environment such architectures should allow communication among nearby vehicles and nearby fixed roadside equipment.

The figure 2 below illustrates the reference architecture. This reference architecture covers three aspects of vehicular communication: In –vehicle, ad hoc and infrastructure domain. The In- Vehicle domain refers to a local network inside each vehicle logically composed of two types of units:
(i) An On- board unit (OBU) and
(ii) One or more application units (AUs)

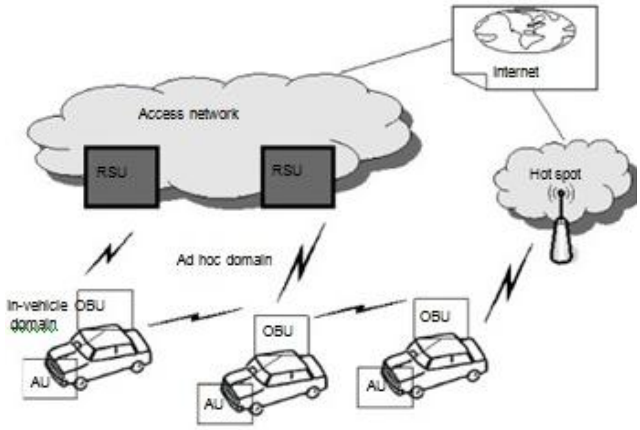

Figure 2: Vehicular Networking Architecture

An OBU is a device in the vehicle having communication capabilities (wireless and/ or wired), while an AU is a device executing a single or set of applications while making use of the OBU's communication capabilities. Indeed, an AU can be an integrated part of a vehicle and be permanently connected to an OBU. It can also be a portable device such as a laptop or PDA that can dynamically attach to (and detach from) an OBU. The AU and OBU are usually connected with a wired connection, while wireless connection is also possible (using Bluetooth etc). This distinction between AU and OBU is logical, and they can very well co-exist as a single physical unit.

The Ad hoc domain is a network composed of vehicles equipped with OBUs and road side units (RSUs) that are stationary along the road. OBUs of different vehicles form a mobile ad hoc network (MANET), where an OBU is equipped with communication devices, including at least short- range wireless communication device dedicated for road safety. OBUs and RSUs can be seen as nodes of ad hoc network, respectively mobile and static nodes. An RSU can be attached to an infrastructure network, which in turn can be connected to the internet. RSUs can also communicate to each other directly or via multi hop approach. Their primary role is improvement of road safety, by executing special applications and by sending, receiving or forwarding data in the ad hoc domain.

Two types of infrastructure domain access exist: RSU and hot spot. RSUs may allow OBUs to access the infrastructure and consequently to be connected to the internet. OBUs may also communicate with Internet via public, commercial or private hot spots (Wi-Fi hot spots). In the absence of RSUs and hot spots, OBUs can utilize communication capabilities of cellular radio networks (GSM, GPRS, WiMax and 4G) if they are integrated in the OBU.

4. Use of Vehicular Collision Warning Communication Protocol

The reduction of traffic accidents can save a lot of human lives. The Vehicular collision warning communication protocol presents a communication mechanism to warn vehicles when an abnormal situation occurs so that they can stop before crashing. This protocol uses the standard 802.11 for the communication between vehicles. Due to the unreliable wireless communication, this protocol must provide reliability by retransmitting packets that did not reach their destination because of packet collisions in network or channel fading.

There are two approaches to establish the way the vehicles will send warning messages. One is the passive approach in which vehicles broadcast their motion information. And the other is the active approach the messages are only send when the problem occurs, that is, when the vehicle acts abnormally. This protocol chooses the active approach because it causes much less traffic in the net. When an emergency occurs (i.e. change of direction, mechanical failure) then the vehicle is said to be Abnormal Vehicle (AV). This Vehicle must send an Emergency Warning message (EWM) to let the surrounding cars to know about this event.

a) Assumptions

In this protocol it is assumed that every vehicle is equipped with a system which is able to get the geographical position of the vehicle. It is also assumed that the vehicle has a wireless transceiver. All vehicles use the same IEEE 802.11 standard and share a common channel. The VCWC protocol does not require all vehicles to be able to send or receive these messages, since this protocol is also helpful when not all the vehicles have a transceiver. Even when the majority of vehicles do not count with this system, the VCWC protocol brings benefits to all vehicles.

b) Message Differentiation

The VCWC uses different types of messages. As they have different priorities, the protocol must support a mechanism of differentiation between messages. Of all the messages, EWMs have highest priority. The forwarded EWMs occurs when the vehicle receives EWM and must spread the warning alert to other vehicles. The third type of message is the non- time sensitive messages, which deal with control tasks. In order to perform this differentiation, the way 802.11 coordinates media access is analyzed. When a vehicle has a packet to transmit, it has to wait for the channel to be idle during the Inter Frame Space (IFS). Then, a random back off is selected to transmit. Different levels of priorities can be established using different IFS. For eg, message with high priority uses a small IFS.

c) Congestion Contorl of EWMs

It is common that more than one AV coexists in time. For example, if a car stops in the highway due to a mechanical failure, it remains sending EWMs messages to approaching vehicles and will remain AV until it is retired from the road. Also, due to the natural chain effect that is produced in emergency events, the coexisting AVs might send messages at the same time, leading to packet collisions. The VCWC protocol has to deal with multiple AVs.

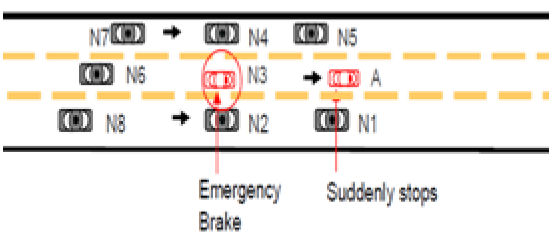

Figure 3: Collision Scenario

Another phenomenon might increase congestion in the network. This is known as Redundant EWMs. In Figure 3 is shown an example of this. Vehicle A suddenly stops, vehicle N3 breaks because of A's detention. In this case, the EWM sent by N3 and the EWM sent by vehicle A are actually warning about the same event.

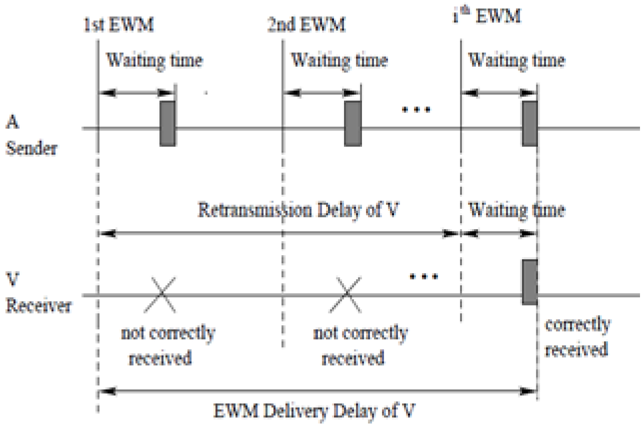

Figure 4: Waiting Time and Re-transmission Delay

To ensure a reliable communication over unreliable wireless channel, EWMs must be repeatedly sent at a certain rate. However, if the retransmission rate is too high, there are more EWM messages travelling in the same time which leads into a high congestion of the network. In addition, as a EWM cannot be transmitted until the previous has been transmitted; the inter-transmission duration of EWMs adds delay to the retransmission delay as shown in Figure 4.

$$Delay = Delay_{wait} + Delay_{retransmission} \quad \ldots. (1)$$

Figure 4 shows the total delay, described by equation 1. Hence, a high transmission rate would contribute to high congestion, increasing the waiting time ($Delay_{wait}$). In the other hand, a low transmission rate would increase the retransmission time ($Delay_{retransmission}$). A good balance must be found. The strategy presented in the VCWC protocol takes into accounts the fact that at the beginning of an accident event the delay must be minimized.

However, once the closer vehicles have been warned, the higher distance with the approaching cars allows a certain delay relaxation. This is shown in Figure 5, where vehicle A must quickly alert vehicle N3, but can offer a bigger delay to warn vehicle N6. This relaxation delay allows the VCWC protocol to reduce the transmission rate, and consequently reduce the traffic congestion in the network.

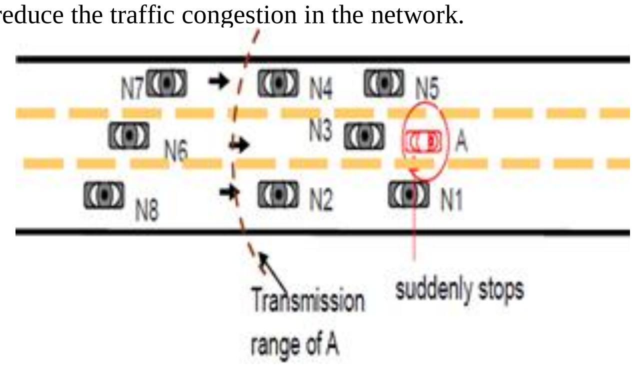

Figure 5: Delay Requirement Relaxation

5. Applications

Vehicular networking applications can be broadly categorized into:
1) Active road safety applications,
2) Traffic efficiency and management applications.

(a)Active Road Safety Applications

Active road safety applications are those that are primarily employed to decrease the probability of traffic accidents and the loss of life of the vehicle occupants. A significant percentage of accidents that occur every year in all parts of the world are associated with intersection, head-on, rear-end and lateral vehicle collisions. Active road safety applications primarily provide information and assistance to drivers to avoid such collisions with other vehicles. This can be accomplished by sharing information between vehicles and road side units which is then used to predict collisions. Such information can represent vehicle position, intersection position, speed and distance heading. Moreover, information exchange between the vehicles and the road side units is used to locate hazardous locations on roads, such as slippery sections or potholes. Some examples of active road safety applications are given below as,

- Intersection collision warning: In this scenario, the risk of lateral collisions for vehicles that are approaching road intersections is detected by vehicles or road side units. This information is signaled to the approaching vehicles in order to lessen the risk of lateral collisions.
- Lane change assistance: The risk of lateral collisions for vehicles that are accomplishing a lane change with blind spot for larger vehicles like trucks are reduced.
- Overtaking vehicle warning: Aims to prevent collision between vehicles in an overtake situation, where one vehicle, say vehicle1 is willing to overtake a vehicle, say vehicle3, while another vehicle, say vehicle2 is already doing an overtaking maneuver on vehicle3. Collision between vehicle1 and vehicle2 is prevented when vehicle2 informs vehicle1 to stop its overtaking procedure.
- Head on collision warning: the risk of a head on collision is reduced by sending early warnings to vehicles that are traveling in opposite directions. This use case is also denoted as “Do Not Pass” warning.
- Rear end collision warning: the risk of rear-end collisions for example due to a slow down or road curvature (e.g. curved hills) is reduced. The driver of a vehicle is informed of a possible risk of rear-end collision in front.
- Co-operative forward collision warning: a risk of forward collision accident is detected through the cooperation between vehicles. Such types of accidents are then avoided by using either cooperation between vehicles or through driver assistance.
- Emergency vehicle warning: an active emergency vehicle, e.g., ambulance, police car, informs other vehicles in its neighborhood to free an emergency corridor. This information can be re-broadcasted in the neighborhood by other vehicles and road side units.
- Pre-crash Sensing/Warning: in this use case, it is considered that a crash is unavoidable and will take place. Vehicles and the available road side units periodically share information to predict collisions.
- Co-operative merging assistance: vehicles involved in a junction merging maneuver negotiate and cooperate with each other and with road side units to realize this maneuver and avoid collisions.
- Emergency electronic brake lights: vehicle that has to hard brake informs other vehicles, by using the cooperation of other vehicles and/or road side units, about this situation.
- Wrong way driving warning: a vehicle detecting that it is driving in wrong way, e.g., forbidden heading, signals this situation to other vehicles and road side units.
- Stationary vehicle warning: in this use case, any vehicle that is disabled, due to an accident, breakdown or any other reason, informs other vehicles and road side units about this situation.
- Traffic condition warning: any vehicle that detects some rapid traffic evolution, informs other vehicles and road side units about this situation.
- Signal violation warning: one or more road side units detect a traffic signal violation. This violation information is broadcasted by the road side unit(s) to all vehicles in the neighborhood.
- Collision risk warning: a road side unit detects a risk of collision between two or more vehicles that do not have the capability to communicate. This information is broadcasted by the road side unit towards all vehicles in the neighborhood of this event.
- Hazardous location notification: Any vehicle or any road side unit signals to other vehicles about hazardous locations, such as an obstacle on the road, a construction work, oil spill or slippery road conditions.
- Control Loss Warning: if an additional use case is described that is intended to enable the driver of a vehicle to generate and broadcast a control-loss event to surrounding vehicles. Upon receiving this information the surrounding vehicles determine the relevance of the event and provide a warning to the drivers, if appropriate.

(b)Traffic Efficiency and Management Applications

Traffic efficiency and management applications focus on improving the vehicle traffic flow, traffic coordination and traffic assistance and provide updated local information, maps and in general, messages of relevance bounded in space and/or time. Speed management and Co-operative navigation are two typical groups of this type of application.

- Speed management: Speed management applications aim to assist the driver to manage the speed of his/her vehicle for smooth driving and to avoid unnecessary stopping. Regulatory/contextual speed limit notification and green light optimal speed advisory are two examples of this type.
- Co-operative navigation: This type of applications is used to increase the traffic efficiency by managing the navigation of vehicles through cooperation among vehicles and through cooperation between vehicles and road side units. Some examples of this type are traffic information and recommended itinerary provisioning, co-operative adaptive cruise control and platooning.

6. Conclusion

Inter- Vehicle communication promises to be an amazing technology that is being developed for future improvements in transportation. This technology has the capability to change the driving and travel experience throughout. IVC is an emerging area of interest in networks and an important area of research. IVC is an outcome of improvements of in-Vehicle computing and also the advancements in wireless communication and mobiles. Inter-vehicle communication has the potential to increase efficiency on the roadways as well as increase in safety.

Designing a protocol for IVC is extremely challenging since it has to deal with the high mobility of vehicles and also offer a secure communication. The VCWC protocol proposed in this paper aims to provide a solution in improving road safety.

7. Future Work

The future work will be to design an IOT based frame work for intervehicular communication.

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