

"System for Reducing Collision Accidents Using the Vehicle-to-Vehicle Communication Model and Wireless Network Mechanisms"

Eyran Roberto Diaz Gurrola¹, Emmanuel Contreras Medina², Carlos Tolentino³, Victor Manuel Moreno Landeros⁴, Alicia Rodriguez Pulido⁵, Iliana Avalos Murillo⁶,

¹²⁴⁵*Departamento de Posgrados de la Universidad Autonoma de Coahuila, México*

³*Instituto Tecnológico Superior de México Campus Saltillo*

⁶*Universidad Politecnica de Gómez Palacio, México*

Abstract:- Information Technologies (IT), have evolved and streamlined technological systems across different industrial sectors, including the automotive industry. This evolution is made possible by research lines addressing problems to be solved or innovations to be implemented. One such problem generally involves the design, development, and implementation of vehicle-to-vehicle communication systems and, particularly, the use of car-to-car systems as a means to reduce the incidence of rear-end collisions between vehicles. Addressing this issue is relevant, considering that there are about 1.7 million annual rear-end accidents in the United States alone, resulting in approximately 1,700 deaths and 500 injuries. This article presents a vehicular communication system based on wireless communication networks for the periodic exchange of information between vehicles to reduce such collisions.

Keywords: Information Technology, Communication, Vehicle-to-Vehicle, Wireless Network.

1. Introduction

The evolution of technology has impacted various sectors such as education, politics, social affairs, and commerce, transforming organizational and work practices (Drucker, 2004). In this context, the main areas of study have been the automation of services and software development driven by technological change (Arriola, 2008). One of the primary sectors experiencing technological change is the automotive industry. Since the early 1990s, efforts have been intensified to integrate transportation system technology to build "intelligent highways" capable of guiding vehicles to improve traffic safety. The effective use of such systems would have a significant impact on global transportation, expected to decrease the likelihood of traffic accidents and human life losses (Shereen A. M. Ahmed, 2013). There are approximately 1.7 million rear-end collisions on U.S. highways each year. About 1,700 people die in these collisions, and another 500,000 are injured. Many of the most common car accidents could be prevented if car manufacturers began to produce autonomous collision systems in their vehicles, said the National Transportation Safety Board (NTSB) (Halsey, 2015). The NTSB estimated that 80 percent of the deaths and injuries resulting from rear-end collisions could be prevented by these systems (Halsey, 2015).

Intelligent Transportation Systems (ITS) are already being harmonized in various countries around the world. Some interests of countries like the United States and Japan are to address the challenges of the transportation system such as congested roads and deteriorating infrastructure, building intelligent infrastructure to meet future demands, and improving the transport network while implementing technologies to save lives, time, money, and to protect the environment (Mohammad Horani, 2012). Currently, vehicles are equipped with GPS systems for better route determination, and there is even information exchange between vehicles. Satellite navigation maps with additional information layers contain current topics observed by the vehicles and transmitted via car-to-car (C2C) for information exchange and not through a centralized infrastructure. Each car is a node in a dynamic

network that can communicate directly only with physically adjacent nodes within a certain range (Walter Balzano, 2014).

Vehicle-to-vehicle (car-to-car) communication allows cars to broadcast their position, speed, steering wheel position, braking status, and other data to other vehicles within a few hundred meters (Knight, 2015). This information can be used to determine the position of different vehicles if it were sent to a real-time network to connect various vehicles and share information. The WAVE protocol (Wireless Access in Vehicular Environment) is currently considered the most promising technology for vehicular networks. Its aim is to support the interoperability and robustness of safety communications in a vehicular environment (Shereen A. M. Ahmed, 2013).

An Ad-hoc network is a wireless communication network that connects nodes to each other; this communication can be established using the IEEE 802.11 standard or other wireless technologies. Within this type of networks, a network can be set up among isolated devices without requiring a base station, fixed routers, etc., or having a system administrator, because they are a type of adaptive, low-cost, and self-configurable network that sometimes requires two or three nodes to be deployed (Broch, Maltz, Johnson, Hu, & Jetcheva). The study of this topic aims to reduce automotive accidents through collisions by exchanging information using vehicle-to-vehicle (car to car) technology, through wireless communication networks.

2. Theoretical Framework

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Mi in nulla posuere sollicitudin aliquam. Egestas diam in arcu cursus. Tincidunt arcu non sodales neque. Id neque aliquam vestibulum morbi. Donec enim diam vulputate ut pharetra sit amet aliquam id. Enim sed faucibus turpis in eu mi bibendum neque egestas. Sed enim ut sem viverra. Donec ultrices tincidunt arcu non. Varius sit amet mattis vulputate enim nulla aliquet porttitor. Ultrices dui sapien eget mi proin sed libero enim. Sem viverra aliquet eget sit. Malesuada nunc vel risus commodo viverra maecenas accumsan lacus vel.

Quis risus sed vulputate odio ut enim. Laoreet suspendisse interdum consectetur libero id faucibus nisl. Egestas maecenas pharetra convallis posuere morbi. Vitae suscipit tellus mauris a diam maecenas. Sit amet cursus sit amet. Dui nunc mattis enim ut tellus. Amet nulla facilisi morbi tempus iaculis. A iaculis at erat pellentesque adipiscing commodo elit at imperdiet. Pulvinar mattis nunc sed blandit libero volutpat sed. Tincidunt ornare massa eget egestas purus viverra accumsan in nisl. Fermentum odio eu feugiat pretium. Tellus mauris a diam maecenas. Tincidunt lobortis feugiat vivamus at. Tincidunt tortor aliquam nulla facilisi cras. Enim neque volutpat ac tincidunt vitae. Amet massa vitae tortor condimentum. Ut tortor pretium viverra suspendisse potenti nullam ac tortor. Convallis aenean et tortor at.

In car-to-car technology, a vehicle can share information with other vehicles or roadside units (RSUs) nearby. Each cooperative vehicle or RSU is allowed to generate a "bird's eye view" of the local traffic situation. The Car2X system infrastructure units can assist the driver in adapting to traffic (Proskawetz D. K.-O.).

In 2012, the U.S. Department of Transportation conducted a pilot test of the car-to-car technology on about 3,000 vehicles from different brands to ensure that the technology works seamlessly, regardless of the manufacturer. The main goal of the project is to prevent traffic accidents and save millions of lives. The car-to-car technology also represents an opportunity to improve mobility in cities, as its eventual implementation would allow for precise knowledge of traffic density and the approximate number of vehicles traveling on a road network (Hermida, 2015).

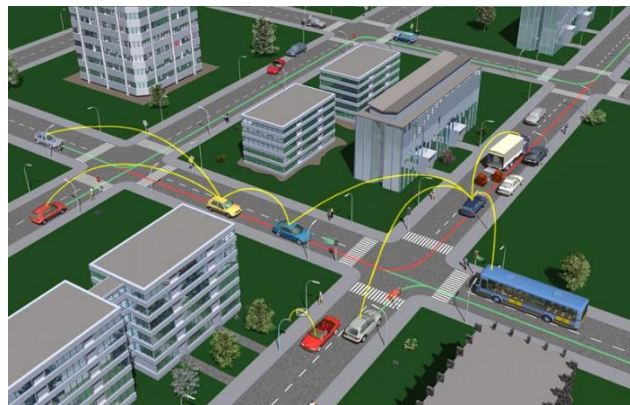


Figure 2. Car-to-Car Communication

Car to Car: New Technological Model

The debate is on the table, or rather, on many desks, as there are many stakeholders eager to leverage this new understanding of road traffic. From car manufacturers to major technology companies specializing in communication systems, to service providers who see the connected car as an even more lucrative market than the boom of apps on smartphones and tablets (Clavero, 2015).

The issue with this entire business fabric lies in the limits that have yet to be imposed for the benefit of the driver as both the generator and owner of that information. Nowadays, the first cars that allow internet connections and information collection services do not provide users with a customization tool to limit the information that is transmitted. Lost in a sea of clauses and paperwork, drivers grant full powers to enjoy the latest in automobile technology in their vehicle (Clavero, 2015).

Currently, vehicles are equipped with GPS systems for better route determination, and there is even information exchange between vehicles. Satellite navigation maps with additional information layers contain current topics observed by the vehicles and transmitted by Car2Car (C2C) for information exchange and not through a centralized infrastructure. Each car is a node in a dynamic network, which can communicate directly only with physically adjacent nodes within a certain range (Walter Balzano M. R., 2015).

There are Intelligent Transportation Systems (ITS), which are already being harmonized in different countries around the world. Some interests of countries like the United States and Japan are to address the challenges of the transportation system such as congested roads and deteriorating infrastructure, building intelligent infrastructure to meet future demands, and improving the transport network while implementing technologies to save lives, time, money, and to maintain the environment (Mohammad Horani A. S., 2012).

The Electronic Stability Program (ESP) has opened the door to active safety. The latest driver assistance systems such as adaptive cruise control (ACC), emergency braking, and lane assistance already contribute to preventing accidents or at least reducing the severity of unavoidable accidents. However, like radar sensors, laser scanners, and cameras, they have limited range detection and in detecting complex traffic situations near the vehicle. To overcome these restrictions, data exchange between vehicles is utilized (Proskawetz D. K.-O.).

Ad-hoc Communication

An Ad-hoc network is a wireless communication network that connects nodes together; this communication can be established using the IEEE 811 standard or other wireless technologies. Within this type of network, a network can be set up among isolated devices without requiring a base station, fixed routers, etc., or having a system administrator, because they are a type of adaptive, low-cost, and self-configurable network that sometimes requires only two or three nodes for deployment (Gálvez Serna, 2009).

Each node can function as a transmitter, receiver, or router, without having a centralized access point; meaning the nodes must be capable of adapting to the network. In this way, at any given moment, a set of independent

devices can establish links with each other and create a network that configures itself without having a pre-existing network infrastructure. Nodes in Ad-hoc networks enable connection to a larger network, such as the internet.

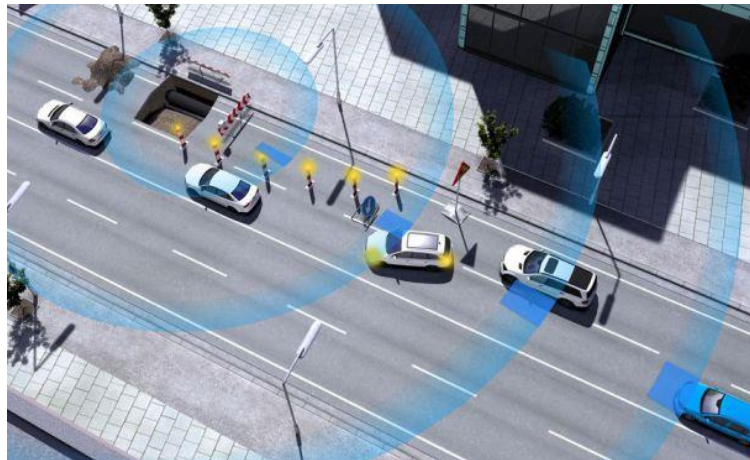


Figure 3. Cars as Communication Nodes

VANET Networks

The characteristics of this network are similar to those of classic Ad-hoc scenarios, due to the fact that the network topology changes rapidly in proportion to the movement that the vehicles experience. However, they have notable differences from traditional Ad-hoc networks. For example, the energy source of VANETs networks is not limited because the vehicles possess a powerful rechargeable energy source. Additionally, vehicles typically move within the same lane on a highway most of the time, which enhances the VANET network (Sánchez Bueno, 2010).

IEEE WAVE Protocol

The IEEE WAVE standard protocol is based on the IEEE 802.11a Orthogonal Frequency Division Multiplexing (OFDM) mechanism, which supports various data rates determined by modulation rate and type coding. In order to accommodate this capability of the single physical layer device, synchronization is required to ensure that all wave devices monitor the Control Channel (CCH) at the same time interval. As soon as a group of wave devices are synchronized at the same time, they can monitor and/or use the control channel. The current WAVE standard adjusts to a synchronization where all wave radio devices align their resources to a precise global clock each time period. Additionally, it can help in reducing pollution and conserving fuel. Vehicular Ad-hoc Networks (VANET) is a kind of large-scale Mobile Ad-hoc Networks (MANET) that turn moving cars into wireless nodes. VANET is characterized by high node mobility, a wide range of relative speeds between vehicles, and the nature of real-time applications (Shereen A. M. Ahmed, Overview of Wireless Access in Vehicular Environment (WAVE) Protocols and Standards, 2013).



Figure 4. IEEE WAVE Model

System Resources

Raspberry Pi

The Raspberry Pi is a mini-computer developed in the United Kingdom by the Raspberry Pi Foundation as shown in the figure. Its primary goal is to stimulate the computing sciences since it features a Broadcom BCM2835 chip with an ARM processor running at 1GHz, meaning it nearly fulfills all the components of a computer.

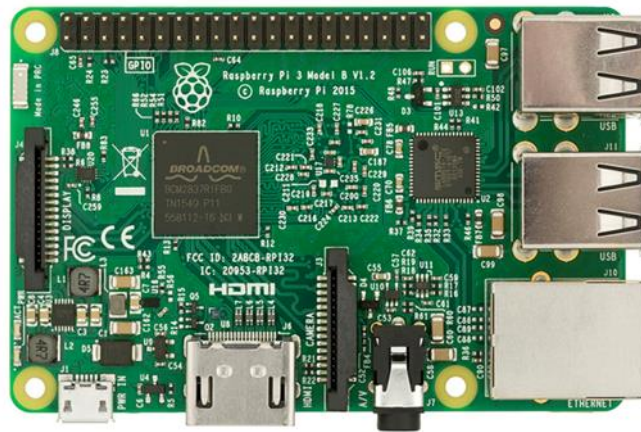


Figure 5. Raspberry Pi

Arduino Nano

The Arduino Nano is a small, complete, and user-friendly board based on the ATmega328 (Arduino Nano 3.x) or ATmega168 (Arduino Nano 2.x). It has roughly the same functionality as the Arduino Duemilanove but in a different package. It only lacks a DC power jack and uses a Mini-B USB cable instead of a standard one. The Nano was designed and is being produced by Gravitech. The Arduino Nano can be powered via Mini-B USB, 6-20V with an unregulated voltage source (pin 30), or 5V from a regulated source (pin 27). The voltage source is automatically selected to the highest power supply available



Figure 6: Arduino Nano

Ultrasonic Sensor

The XL-MaxSonar has a range of 10 meters outdoors and is a robust module resistant to the elements. This outdoor sensor provides both long and short-distance detection, protected by a compact PVC casing. This ultrasonic sensor complies with the IP67 standard; it matches standard 3/4 inch PVC pipe fittings as shown in figure 25.

It features high acoustic power output, combined with continuous variable gain, real-time automatic calibration, and includes algorithms for noise rejection, resulting in virtually noise-free distance readings.

If the application requires additional chemical resistance, the model F is also available, which provides our sensors with not only weather resistance but additional protection against corrosive chemical environments



Figure 7: Ultrasonic Sensor

3. Methodology

Research Design

For the completion of this work, several types of research were considered, detailed as follows:

Applied Research:

This seeks the application or use of knowledge and technological advancement that is acquired. This type of research depends on the results of basic research, with the researcher interested in the practical consequences observed.

Bibliographic Research:

The means on which the theoretical phase of this document is based include books, journals, scientific publications, etc.

Descriptive Research:

This involves measuring and evaluating various aspects, dimensions, or components of the phenomenon under investigation.

Experimental Research:

This relates to experiments and applications to verify communication between raspberries, sensor – Data acquisition card (Raspberry) and Data acquisition card (Raspberry)-PC for car-to-car communication.

Hypothesis

H1: The design and implementation of a communication system with the car2x Model will prevent vehicular accidents by collision.

Procedure

For the development and implementation of a communication system, a series of processes were followed, which together will achieve the desired objective. The following are the steps to be followed in the research:

Configuration of the operating system on the data acquisition card (Raspberry)

Configurations of the ad-hoc network.

Installation of the VNC client-server program on raspberry 1 assigned as Client and raspberry 2 assigned as Server

Installation and configuration of the MB7076 Ultrasonic Sensor on Raspberry Pi 2B through the Arduino interface

The development and implementation of an integrated system for preventing traffic accidents in automobiles. The system operates over an AD-HOC network where real-time transmission is carried out using 2 Raspberry Pi 2B units.

For potential obstacles that may appear in front of the vehicle to which the Raspberry is connected, the MB7076 Ultrasonic Sensor was used.

Results

This section outlines the development and implementation of an integrated system for the prevention of automotive collisions. The system operates over an AD-HOC network where real-time transmission is carried out using 2 Raspberry Pi 2B units. It is important to note that Arduino boards facilitate communication. For vehicle-to-vehicle communication, 2 protoboards with the MB7076 Ultrasonic Sensor were used because the previously proposed electronic device could not be utilized due to its relatively high cost and lack of a secure distribution account for its acquisition.



Figure 8: System Integration in the Prototype

Source: Own

System Configuration and Application

For this activity, initially two random IP addresses that are within the same range or class must be established. For example, if we assign a Class A IP address with its default mask to the Raspberry Pi, the other computer should have similar characteristics.

PC	Dirección IP	Mascara	Gateway
Raspberry Pi	192.168.1.3	255.255.255.0	192.168.1.1
Server	192.168.1.4	255.255.255.0	192.168.1.1
Raspberry Pi (Cliente)	192.168.1.2	255.255.255.0	192.168.1.1
CI	192.168.1.5	255.255.255.0	192.168.1.1

Table 1: IP Addressing of Communication Devices

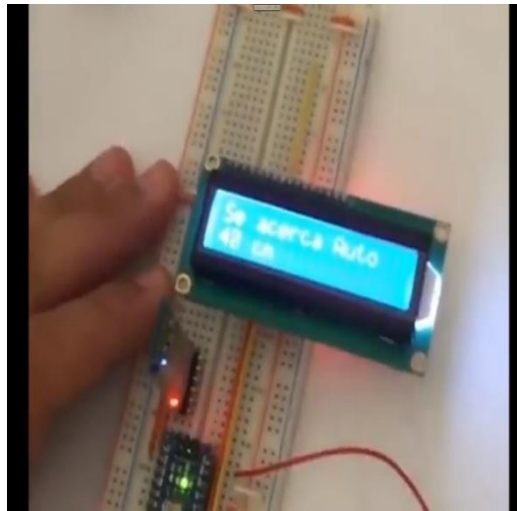


Figure 9: Communication Configuration

Source: Own



Figure 10: Sensor Calibration in Prototype

Source: Own

4. Discussion

For the car-to-car model, in test mode, IEEE is working on the WAVE standard, which is an improvement of the 802.11a, based on short-range wireless access technologies in the adhoc vehicular network environment known as VANETs. This technology allows for the exchange of information, such as audio/video, alarms, and configuration updates.

The ad-hoc network created by the Raspberry's WiFi adapter can transmit over short distances because its power is not very far-reaching. The vehicular communication system is within a range of 10-15m, and for information exchange to occur, the following must be met: the second vehicle must travel at a speed that does not exceed the first vehicle, as this system is limited by the connection time and the distance between vehicles for real-time transmission. The alarm system activates within a range of 4-6 meters, providing the opportunity to react in time to any dangerous situation.

Electronic systems are very helpful for all sorts of requirements, one of which is the exchange of information provided by data acquisition cards (Raspberry). The Wireshark program allows viewing the number of packets

received from information transmission within the Ad-Hoc communication network, thus providing a successful packet transmission.

By leveraging the advantages of the devices previously used, this system efficiently aided in the transmission of information in reducing accidents using real-time communication.

Conclusions and Recommendations

Upon concluding this research, the following conclusions are drawn:

For the v2v protocol, the frequency of 4.87 GHz (WAVE) is in the process of standardization and will be responsible in the future for supporting communications to improve their performance in the vehicular environment.

Communication between Raspberry devices using the Ad-Hoc network enables efficient and continuous exchange of information between vehicles in real time. The transmission of information is complicated by the fact that both the transmitter and receiver are in motion; these variables can distort the signal, as well as affect the time it takes to connect to the system.

Following the conclusions of the research, the following recommendations are proposed:

For the implementation of a communication system between data acquisition cards (Raspberry), it is necessary to understand the configuration characteristics and operating systems that can be adapted for the applications that are intended to be carried out.

When implementing the Ad-hoc communications network, a thorough analysis of the characteristics and possible configuration alternatives should be performed, such as the Xbee communications network, which is focused on the exchange of information.

References

- [1] Álvaro Cuervo-Cazurra, M. A. (2014). Building Chinese Cars in Mexico: The Grupo Salinas-FAW Alliance. *Innovar*, 219-230.
- [2] Analysis., N. C. (2017). Traffic Safety Facts. Report No. DOT HS 812 393. Rural/urban comparison of traffic fatalities, https://www.washingtonpost.com/news/dr-gridlock/wp/2015/06/08/there-are-about-1-7-million-rear-end-collisions-on-u-s-roads-each-year-heres-how-to-stop-them/?utm_term=.a10036e3b8ed.
- [3] Arriola, O. y. (2008). Sistemas integrales para la automatización. http://scielo.sld.cu/scielo.php?pid=S1024-94352008001200009&script=sci_arttext.
- [4] Broch, J., Maltz, D. A., Johnson, D. B., Hu, Y.-C., & Jetcheva, J. (n.d.). A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols. Computer Science Department, <https://classes.soe.ucsc.edu/cmpe257/Spring03/papers/broch98performance.pdf>.
- [5] Drucker, P. (2004). *La Sociedad Poscapitalista*. Colombia: Editorial Norma.
- [6] Halsey, A. (2015). There are about 1.7 million rear-end collisions on U.S. roads each year. Here's how to stop them. The Washington Post, https://www.washingtonpost.com/news/dr-gridlock/wp/2015/06/08/there-are-about-1-7-million-rear-end-collisions-on-u-s-roads-each-year-heres-how-to-stop-them/?utm_term=.a10036e3b8ed.
- [7] Knight, W. (2015). Car-to-Car Communication. MIT Technology Review.
- [8] Mohammad Horani, A. S. (2012). Emerging Technologies Comparison in the United States, Europe, and Japan. *AutomotiveWorld*, <https://s3.amazonaws.com/automotiveworld/presentations/V2V+-+Car2Car+Comparison.pdf>.
- [9] Mohammad Horani, A. S. (2012). V2X – Emerging Technologies Comparison in the United States, Europe, and Japan. *AutomotiveWorld*.
- [10] Proskawetz, D. K.-O. (n.d.). Cooperative Intelligent Transport Systems and Services (C-ITS) - Car2Car and Car2Infrastructure Communication facilitates a huge potential for intermodal and sustainable mobility -. Managing Director of ITS Niedersachsen GmbH.

-
- [11] Proskawetz, O. (2016). Cooperative Intelligent Transport Systems and Services (C-ITS) - Car2Car and Car2Infrastructure Communication facilitates a huge potential for intermodal and sustainable mobility. Managing Director of ITS Niedersachsen GmbH, https://eu-smartcities.eu/sites/all/files/docs/best-practice/Car2X_topic_description.pdf.
 - [12] Schütze, D. T. (2011). Automotive Security: Cryptography for Car2X. Rohde & Schwarz.
 - [13] Schütze, D. T. (2011). Automotive Security: Cryptography for Car2X. Rohde & Schwarz, http://www.torsten-schuetze.de/reports/ieee1609-2_security.pdf.
 - [14] Schwarz, C. f. (2011). Overview of Wireless Access in Vehicular Environment . Indian Journal of Science and Technology.
 - [15] Shereen A. M. Ahmed, S. H. (2013). Overview of Wireless Access in Vehicular Environment (WAVE) Protocols and Standards. Indian Journal of Science and Technology, <http://www.indjst.org/index.php/indjst/article/view/34355>.
 - [16] Shereen A. M. Ahmed, S. H. (2013). Overview of Wireless Access in Vehicular Environment (WAVE) Protocols and Standards. Indian Journal of Science and Technology.
 - [17] Walter Balzano, M. R. (2014). A Smart Framework for GPS Trajectories' Segmentation. International Conference on Intelligent Networking and Collaborative Systems.
 - [18] Walter Balzano, M. R. (2015). SoCar: a Social car2car framework to refine routes information based on road events and GPS. 2015 IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing.