V2V Communication System to Increase Driver Awareness of Emergency Vehicles

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Abstract. Intelligent Transportation Systems (ITS) applications are supported by systems relying on Dedicated Short-Range Communications (DSRC). This paper presents the implementation steps for a vehicle to vehicle (V2V) communication system intended to increase driver awareness of the surroundings in an emergency situation. Particularly, the system broadcasts basic safety warning messages between an emergency vehicle and other vehicles in the vicinity. The field experiment on communication performance showed that the connection could be established within a range of 20 meters. Furthermore, the range could be increased by adding a third communication device and using it to resend the message.

Keywords: Vehicle-to-Vehicle communication, Emergency Warning System, DSRC

1 Introduction

According to the World Health Organization (WHO, 2012) fatalities caused by road injuries increased from 1 million in 2000 to more than 1.2 million in 2012. The implementation of road warning messages is intended to increase awareness of dangerous situations, decrease reaction time to them and thereby lower the overall chances of an accident.

Intelligent Transport Systems and Services (C-ITS) enable wireless communication between vehicles and/or traffic infrastructure using a standardized set of messages that are based in the real-time transfer of data. Applications related to Intelligent Transportation Systems (ITS) are supported by systems relying on Dedicated Short-Range Communications (DSRC) that consist of Road Side Units (RSUs) and On Board Units (OBUs) with transceivers and transponders [1]. Vehicle to vehicle (V2V) communication uses IEEE 802.11 or ITS-G5A/B/D standards which operates in 5.9GHz with a bandwidth on 75MHz and a range of 1000m [2].

This paper presents the implementation steps for an Emergency Warning System (EWS) that relies on V2V communication to increase driver awareness of the surroundings in an emergency situation. Particularly, the system broadcasts basic safety

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warning messages between an emergency vehicle and other vehicles in the vicinity. Fig. 1 depicts the communication process.

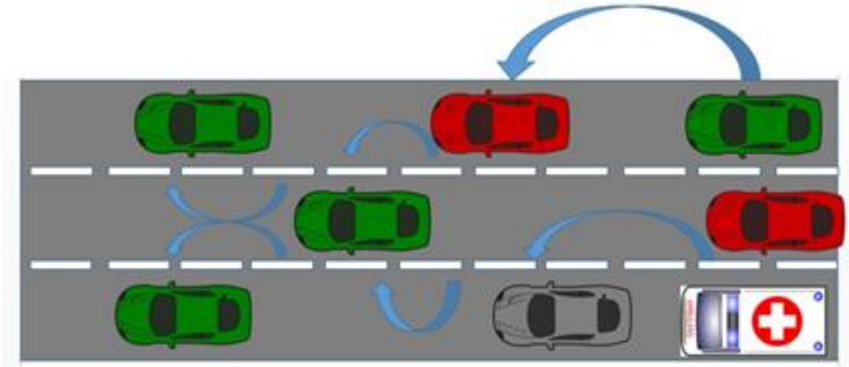

Fig. 1. V2V communication example for an EWS.

2 Related Work

V2V communication is a very extensive area for research and development. For example in [3] a heterogeneous wireless network performance evaluation was performed in vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. The authors demonstrated the potential of V2V and V2I in heterogeneous networks (HetNet) with Wi-Fi, DSRC and LTE, which guarantees the optimal utilization of available communication options and minimizes the corresponding backhaul communication infrastructure requirements while considering connected vehicle application requirements.

Additional works studied traffic volume estimation by V2V communication [4] or V2X communication for efficient control of fully automated connected vehicles at a freeway merge segment [5].

In [6], authors focused on recently proposed V2V MAC schemes and gave a detailed review of each alongside their strengths and drawbacks. They also discussed pros and cons of V2V MAC, and different ways to achieve communication similarly to [7], in which the radio channel for 5G V2V communications was set at two millimeter wave frequency bands.

In the same line of research, the authors in [8] experimentally characterized V2V millimeter wave radio channel at 38 GHz and 60 GHz frequency bands and related the channel behavior they observed with the measurement environment and setup.

However, in the study presented here, DSRC was used because of the better connection time and signal range, as our focus is on sending a warning message in an emergency situation Utilizing this method, each vehicle functions as an antenna and we can convey our message through a V2V channel so that a clear path can be created for vehicles to take in case of passing an ambulance or police patrol.

3 Technical Implementation

Relying on [3] we implemented a Basic Safety Message (BSM) that is used to exchange safety data regarding vehicle state. The message was broadcast routinely to surrounding vehicles and contained information regarding longitude, latitude and vehicle identity. In order to locate the vehicles, we used an Adafruit Ultimate GPS antenna. Once the BSM was generated, the message was wirelessly transmitted to another vehicle by using the NRF24l01 LNA wireless module. Table 1 summarizes the described components.

In order to make sure that the broadcast BSM was properly obtained, we relied on a receiver with DSRC capabilities. The system also included a computer processing unit that was able to decode the BSM properly and a GPS antenna to verify the relative distance between the sending and the receiving device. In order to convey the message to the driver in an adequate way, we developed an in-vehicle interface to display the warning through a 12*2 LCD display.

Table 1. Communication System Components

Hardware	Sender Hardware		Receiver Hardware
GPS Receiver		Adafruit Ultimate GPS	
Processor		Raspberry Pi	
Antenna		NRF 24L01	
Interface	---------		16*2 LCD

4 V2V Communication

To establish vehicle communication an accurate and trusted BSM needs to be transmitted and received.

4.1 Message Sending Process

Once its position is known with a GPS sensor, a computer processing unit (Raspberry pi 2) combines the location coordinates with other onboard sensor information (e.g., speed, heading, acceleration) to generate the required BSM data string (see Fig. 2).

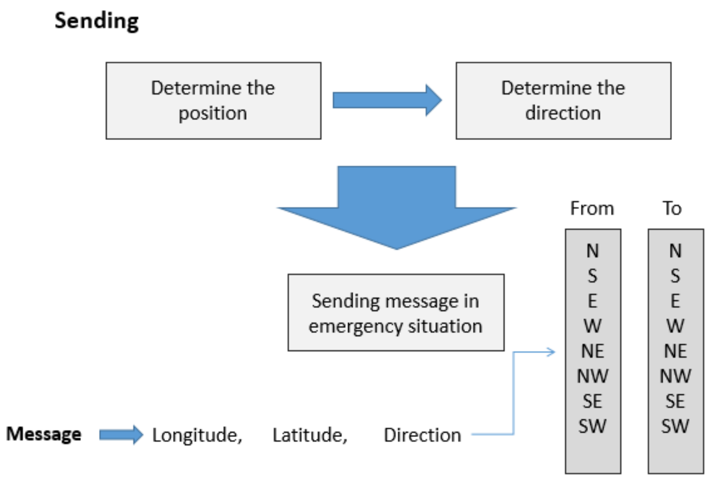

Fig. 2. Message Sending Process

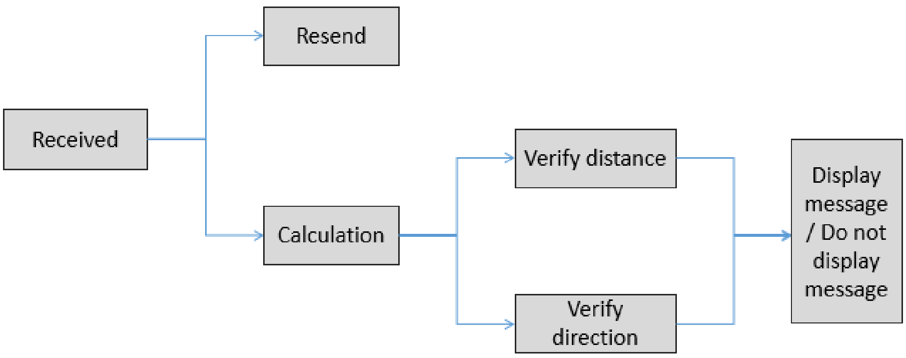

Fig. 3. Message Receiving Process

4.2 Message Receiving Process

In order to establish a connection between 2 vehicles they must be capable of receiving the BSM that is transmitted from a nearby (vehicle) device and it must match the method of BSM transmission (i.e., if the message is transmitted via Dedicated Short Range Radio Communication (DSRC), the receiving device must have a DSRC receiver). It also must have a computer processing unit that can decode the BSM properly. A GPS antenna and receiver is needed to verify the relative distance between the sending device and the receiving device. Fig. 3 illustrates the message sending process.

5 System Evaluation

The implemented prototype was tested under both lab and real-life conditions. Under lab conditions the devices were able to show the intended emergency message.

Because this system is based on the GPS signal, lab condition tests revolved around sending and receiving the message and how to resend the message to another device. During the field tests, one device was positioned in a vehicle that was marked as an emergency vehicle. The second device was located in a different vehicle. Both devices were capable of sending a message within a range of 20 meters. Furthermore, the range could be increased by adding a third device and using it to resend the message.

In order to calculate the maximum possible throughput of a data transfer between the 2 devices, the maximum distance the data could be transferred was calculated for 100 times within 20 days in various situations (i.e., different weather conditions, narrow street with high density, main and secondary street). The results of the evaluation of the developed system are shown on Fig. 4. When the connection was lost, the position of each car was recorded and, based on the recorded position, the point to point distance between cars was calculated. Throughout this test the maximum distance between two cars was 189 meters, which was performed in a broadway, and the minimum distance was 85 meters. The aforementioned test was performed in some narrow streets of inner-city Vienna.

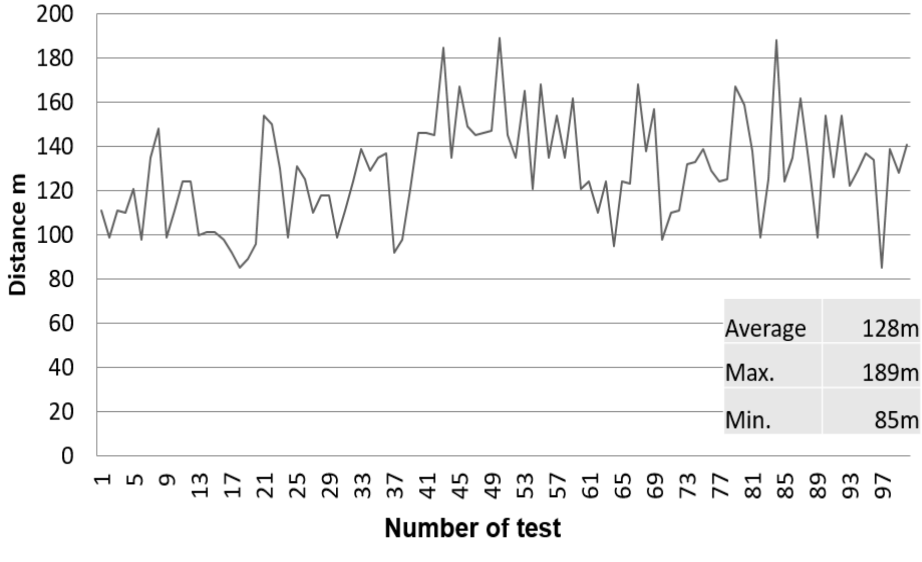

Fig. 3. Results of the prototype evaluation under real-life conditions

6 Conclusion and Future Work

C-ITS have the potential to enhance safety on roads by providing early warnings. However, the success of V2V communication depends on having a fast and reliable network connection, cyber security for V2V and privacy protection. In this paper we presented an Emergency Warning System that relies on V2V communication to increase driver awareness of the surroundings in an emergency situation. Further implementation will determine the direction of movement in cross sections and the position of the vehicle on different roadways.

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