

An Adaptation of DSRC Protocol for V2V Communications in Developing Countries: End-to-End Delay Evaluation

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Abstract

Vehicular Ad hoc NETWORKS (VANETs) help in improving road traffic safety and efficiency. In V2V communications, vehicles exchange kinematic information over a suitable protocol in order, either to warn other vehicles of a dangerous situation or inform them about the current status of the traffic flow. When using Wireless Access in Vehicular Environments (WAVE), also referred to as Dedicated Short Range Communication (DSRC) protocol, kinematic information is called Wave Short Messages (WSM), based on Basic Safety Message (BSM) defined by the SAE J2735 dictionary set. BSM is used for safety advertisement, either in one hop or multi-hop broadcasts. However, DSRC evaluations in many urban and sub-urban environments have shown that this protocol is highly sensitive to transmission conditions such as the density and speed of vehicles, antenna position, interference, etc., which makes it difficult to predict its performance. In this paper, we are interested in evaluating, based on various scenarios, the end-to-end delays when a particular emergency vehicle broadcasts BSM to all its nearby vehicles. The results are obtained by modeling and simulating a modified version of the DSRC protocol to fit the Cameroonian environment. Our results reveal that our adapted version of DSRC protocol performs very well and outperform others proposed protocols.

Keywords: Intelligent Transportation Systems (ITS); Vehicle-to-Vehicle communication (V2V); DSRC/WAVE; End-to-end delay; Network simulation.

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1. Introduction

In developing countries, transportation systems experience considerable problems such as road traffic accident and congestion with the proliferation of private vehicles [1]. Intelligent Transportation Systems (ITS) play a *non-negligible* role in reducing road traffic problems. The authors of [2] explain that since the first introduction of Vehicular Ad Hoc Network (VANET) in 2001, it has been widely perceived by government, car manufacturing industries, and academia as a promising concept for future realization of Intelligent Transportation System (ITS). VANET was then considered by these various actors as a means to achieve *safety and efficiency in the motorway*. To date, various standards have been implemented to accommodate Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications for safety-related applications. One of the various standards *that have* been proposed for such vehicular communication is the short to medium range wireless communication protocol known as Dedicated Short Range Communication (DSRC). Communication can directly be established wirelessly either among vehicles or between a vehicle and a Road Side Unit (RSU). This capability enables car manufacturers to equip vehicles with different sets of communicating units going from wireless sensors to network interfaces. The integrated communicating units thus represent a great opportunity to successfully achieve ITS. This is done by enabling the sending and receiving of kinematic data while on the road. The kinematic information contains the vehicle's current location, intersection position, speed, acceleration and direction of movement. The kinematic information helps to create awareness of the presence of other vehicles on the road. Using VANET, information that can be gathered, processed and distributed among road users are used to provide two types of application services: safety and non-safety. Safety applications are used to reduce (and at best eradicate) the percentage of emergency situations, such as accidents and chronic congestion. They effectively assist drivers by providing them with life-saving information. The provided information is time-sensitive and this information will be useful to the drivers only if only if it is exchanged within an acceptable time-frame. Numerous authors have proposed some solutions to improve communication latency in V2V [3]. Despite these efforts, issues concerning communication delays remain. One of the recommendations is modifying protocols in charge of controlling communication and congestion [3]. In this regards, this paper investigates the end-to-end delay between vehicles in case of emergency situations such as a badly parked vehicle or an accident. An adapted version of DSRC protocol is implemented and evaluated. More specifically, this work evaluates the performance of an adapted version of DSRC in term of end-to-end delays with intensive simulations on the well-known OMNeT++ with its extension framework Veins for vehicular communications, coupled with the mobility generator SUMO. The aim of this work is to study the incidence of received packets latency over V2V communications for safety-related applications. Three conclusions are drawn out of the results: latency increases slightly while the data packet size increases. The latency does not depend on the number of targeted vehicles that is to say that, be it 100 or 500 targeted vehicles, the latency will still be the same. Most important, the adapted version of DSRC we based our experiment on is at least four times effective than related studies. Results show that the worst case is even lower to the DSRC allowable latency. This work has potentials for advancement in that domain. The rest of the paper is organized as follows. Section 2 briefly presents some background studies regarding the end-to-end delays of the DSRC protocol and discusses previous relevant researches. Section 3 presents the proposed adaptation of DSRC and experiment methodologies; Section 4 presents and discusses results. The document ends with a conclusion and

perspectives.

2. Background and related work

This sections describes relevant concepts and research works dealing with objectives.

2.1. DSRC Channel Management

DSRC is a protocol suite designed for low latency networking and used in Wireless Access in Vehicular Environment (WAVE). According to [5], Wireless Access in Vehicular Environment (WAVE) is designed to support ITS applications. It operates in the dedicated Short Range Communication (DSRC) frequency band (5.8 GHz – 5.925 GHz) which in turn operates in the 5.9GHz band with 75MHz spectrum dedicated for VANET's applications. DSRC is divided into 5 MHz guard band and seven 10 MHz channels. One of them is designed as the Control Channel (CCH) and is exclusively dedicated to transmitting safety and control messages. The remaining six, called Service Channels (SCHs), are used to transfer data packets of non-safety applications. The coordination between these channels is made possible through the use of coordinated universal time (UTC), where each second is partitioned into ten synchronization intervals (SI). Each SI consists of one CCH interval (CCHI) followed by one SCH interval (SCI) as shown in Figure 1. Vehicles are all turned into CCH during CCHI to avoid missing safety messages. After the CCHI, vehicles can optionally switch to one of the SCHs during SCI; and for our study, we have chosen to not switch vehicles into SCH because we wanted to evaluate latencies while exchanging safety messages. The channel 178 is the defined CCH and is reserved for safety applications such as collision avoidance, emergency vehicle warning, etc.

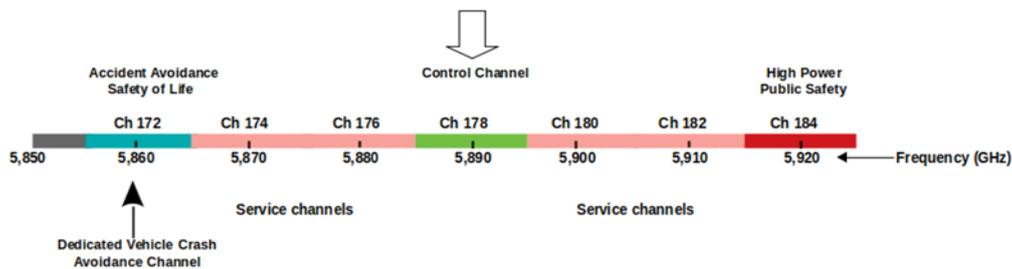


Figure 1: IEEE 802.11p WAVE frequency spectrum

2.2. Latency requirements for DSRC safety-related applications

In VANET, vehicles which are continuously connected to each other based on V2V and/or V2I techniques exchange much information related to their cooperation for safety or comfort services. The DSRC protocol operates via a DSRC radio, which is a short to medium range radio working in the frequency band. A DSRC radio works either inside a vehicle as an On-Board Unit (OBU) or at road-side as a Road Side Unit (RSU). According to [6], DSRC OBU is capable of broadcasting several types of messages specified by the Society of Automotive Engineers (SAE) 2735 protocol. Basic Safety Message (BSM) is the most important message type to be broadcasted by each OBU at a certain frequency (10 Hz). Vehicular safety communications consortium

has provided eight potential safety-related applications listed in Table 1.

Table 1: Allowable latency for some safety-related applications

Safety application	Allowable latency (in sec)
Traffic signal violation warning	0.1
Curve speed warning	1.0
Emergency Electronic brake lights	0.1
Precash sensing	0.02
Cooperative forward collision warning	0.1
Left turn assistant	0.1
Lane change warning	0.1
Stop sign movement assistance	0.1

Safety-related messages from these applications normally require direct communication owing to their stringent delay requirement [3]. For instance, in case of sudden hard breaking or accident, vehicles not involved in the drama are notified by the emergency situation. Applications for road safety are primary measures to reduce (or eliminate) the probability of traffic accidents and loss of life throughout motorways. Some of the traffic accidents that occur annually across the world are as a result of intersection, rear-end, head-on and lateral mobile vehicle collisions [3]. The necessary precautionary measures (or traffic warning systems) required for the effective implementation and deployment of this road safety applications with their required use-case, mode of communication, minimum transmission frequency is of great interest.

2.3. Description of the adapted version of DSRC

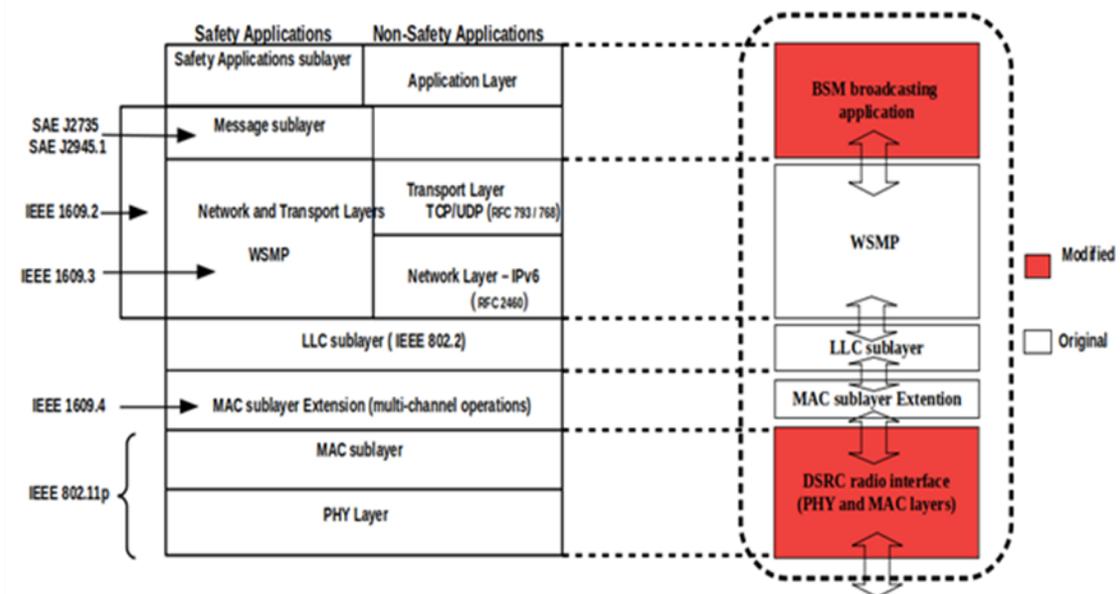


Figure 2: Internal constitution of a DSRC OBU in a vehicle

In the DSRC version we propose, a node, which is represented by a vehicle, is made up of a wireless interface

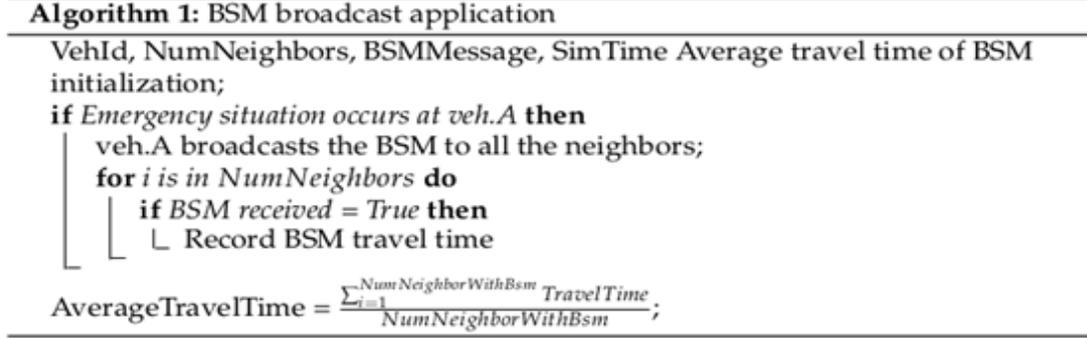
and an application layer. Practically, we assume that each vehicle is equipped with a DSRC OBU. The DSRC OBU is internally made up of three main boxes representing either one (for the case of the application layer) or two (for the case of the wireless interface composed by a PHY and a MAC layer) layers in the traditional DSRC protocol stack as shown in Figure 2. Regarding the traditional DSRC protocol at the left of Figure 2, we have at the top of the WAVE protocol stack, according to vehicular environments, IEEE 1609.3 defines an efficient mechanism to manage safety. The IEEE 1609.3 standard manages the addressing and routing services in the network. Technically, it defines the WAVE Short Message (WSM) and WAVE Short Message Protocol (WSMP) which both provide network and transport layer functionality for road safety applications. Due to its low latency, the use of WSMP is adequate for safety applications. The standard also defines the WAVE Service Advertisement (WSA), which announces the availability of DSRC services. DSRC services allow the control of some applications by announcing their technical characteristics at a given location. WSMP represents bandwidth-efficient small messages exchanged between vehicles or vehicles and Road-Side-Units (RSU) in order to provide road safety. Then come SAE J2735 and SAE 2945.1. In fact, in cooperation with IEEE 1609 standards, the Society of Automotive Engineers (SAE) International has standardized SAE J2735 for Message Set Dictionary used by WSMP and J2945.1 draft for minimum performances requirements [3]. The SAE J2945/1 standard specifies the minimum performance requirements for on-board vehicle-to-vehicle (V2V) safety communications and is in charge of transmitting and receiving Basic Safety Messages (BSMs) over a DSRC wireless communication. Finally, the safety application sub layer is found at the most top of WAVE/DSRC stack

Now, at the right, where we find our adapted version of DSRC, we have implemented three new layers:

- The application layer: which is in charge of messaging the sending and receiving BSMs;
- The radio interface which is made up of:
- The MAC layer; which defines the used data rates, data packet sizes and the transmission power;
- The Physical layer: which defines the various parameters set for V2V transmissions such as the path loss model, the maximum distance between vehicles, the sensitivity threshold of the antenna, the interferences generated by the environment and the obstacles?

2.2.1. Setting up the DSRC OBU: the custom BSM broadcasting application

Various applications are implemented at the application layer of veins' framework. We have built our own application in order to fulfill what we would like to do in our scenario. The pseudo-code given in Figure 6, implements a scenario where, around a crossroad, a random vehicle is found in an emergency situation. After a fixed time, the emergence vehicle broadcasts its state by sending a BSM to all the surrounding vehicles in order to warn them. We are interested in knowing how long it takes for a BSM in this scenario to reach the surrounding nodes. The aim is to record all the individual BSM travel time from the emergency vehicle to any vehicle in the neighborhood that has received the BSM. At the end, the average time will be computed for a batch of simulation in order to estimate the travel time.

**Figure 6:** BSM broadcast application

2.2.2. Setting up the DSRC OBU: the DSRC radio interface

The DSRC OBU is actually the radio interface and it is made up of the physical and the MAC layers. Thus, modifying the DSRC OBU is done by the modification of the physical and the MAC layers.

- The physical layer

In table 2 below, we have changed some predefined parameters in order to meet our needs. In fact, the experiment we have worked on is particular because it is different from what is usually seen in developed countries.

Table 2: Physical layer parameters changed

Parameters and values	Comments
Path Loss Model = Free Space Path Loss $FSPL = 10 \log_{10} \left(\frac{4\pi d}{\lambda} \right)^2 \quad (1)$	For the sake of simplicity, antennas follows the FSPL model denoted in (1) in terms of wavelength. Where d is the distance between the sender and the receiver and λ the wavelength.
Computation of the maximum distance between vehicles d $d = 0.00404913 \times 10^{\frac{-T}{20}} \sqrt{P_{transmit}} \quad (2)$ $P_{recv} = P_{transmit} \left(\frac{cd}{4\pi f} \right)^2 \quad (3)$	d is computed with the sensitivity threshold T and the transmission power $P_{transmit}$ of the DSRC radio antenna and the frequency as defined in the background section.
The maximum interference range = 500m	
Obstacles = considering medium size buildings, hills and trees	Constants that are defined.

- The MAC layer

Table 3: MAC layer parameters changed

Parameters and values	Comments
Transmission Power = 20mW	According to DSRC literature, channels between 172 and 183 use various transmission powers in the world from 23dBm to 44.8dBm. In Europe and Cameroon, 33dBm (20mW) is used.
Bitrate = {3,6,9,27}Mbps	3, 6, 9 and 27 Mbps have been used in order to see the impact of the data rate in transmission.
Data Packets size = {300,500}B	Two different data packets size used.

The purpose of this study is to evaluate the latency of safety-related packets sent over DSRC V2V communications in the capital city of Cameroon, Yaounde. In vehicular networks, safety-related applications usually operate based on wireless broadcast since warning messages need to be delivered to all nearby vehicles. So, when emergency situations occur, either the emergency vehicle itself or vehicles that have detected the emergency broadcast the emergency messages to nearby vehicles by a single-hop packet broadcast. The elapsed time between the sending of the emergency message and its reception is then measured and evaluated in order to see whether the system is reliable or not. Many research works have already been done in this area and some of them are presented the following subsection.

2.4. Related work

V2V communication require fast acquisition, fast message delivery (i.e., low latency) with high reliability when they are sent. While doing it, a vehicle learns a crash or traffic-jam in advance and has the ability to take adequate actions. Zhang and his colleagues [5] demonstrated the importance to put in place intelligent solutions to improve V2V communications deal with traffic congestion dealing with congestion. In this work, the authors have shown that the specific implementation of ITS through DSRC can reduce the travel time and commute time significantly, especially during rush hours. This is different from our proposal in the way that here, the DSRC standard in used to improve the traffic flow through the reduction of the travel time of vehicles on the road during rush hours. Some other works, similar to what we are looking for, are those who provide solutions to improve time taken to inform other vehicles in case of crashing. One of the first investigations of DSRC was made by Yin and his colleagues [6]. In this work, the authors have studied the performance of DSRC vehicular ad hoc networks in terms of bit error rate, throughput and latency. Authors recommended some improvements by exploiting the multi-channel capability of DSRC and by developing other empirical measurement models.

This is different from what we would like to do in terms of channel utilization. In fact, we would like to evaluate the latency of safety-related message sent over the Control Channel (CCH) in V2V communication using the DSRC standard. Dey and his colleagues [8] proposed to combine LTE, Wi-Fi with DSRC to overcome the limited range of DSRC. In doing so, their solution ensured communication reliability to ensure an optimal utilization of alternate communication options. However they are not able to provide better latency time in case of crash: i.e. less than 200 ms, according to DSRC standards, what we are doing in our study. Paranjothi and his colleagues [9] provided an approach to deal with disruption of radio wave propagation between vehicles. They proposed Hybrid-Vehfog, a fog computing based approach, to make robust the dissemination of messages in obstacle shadowing regions. Although simulations showed that their proposal requires less time for end-to-end communications compared to existing approaches, Hybrid-Vehfog remains more latent than the allowable precash sensing latency (i.e. 0.02s). Although the good result obtained, still it is not enough because in a case of a crash, the neighboring vehicles should be informed as soon as possible in order to guarantee more safety. According to [10], reducing latency in V2V communications remains a preoccupation. One of their recommendations is to modify protocols that control communications and congestion. In this regards, we have evaluated our designed adaption version of DSRC for V2V communication in the city of Yaounde. This study focuses on the evaluation of its performance in term of latency.

3. Experimentation and results

Experimentation is done on a particular crossing in Yaoundé at the Accacia corner.

3.1. Environment of simulation

The choice of this place is justified by the fact that Accacia crossing is particularly congested in rush hours and typically fits for Sub-Saharan cities: steep streets, low buildings, almost no pedestrian paths and few lanes. It is located at the GPS coordinates 3.840882, 11.488631 and is depicted in Figure 3. A rectangular zone of 1500m x 1500m represents this area composed of two main streets (SW, NE : N,E) intersecting at one point (3.840882, 11.488631). Each of these streets has four lanes, two in each direction, but the delimitation is not clear and is often violated.



Figure 3: Experiment location

The intersection (the area with the name Carrefour Accacia) is on top of a small hill, with three of the adjacent roads sloping. Road (SW,NE) has a vertical drop of 22 m at point A, and is about 1 km long. Whereas road (N,E) has a vertical drop of 25 m from A to East, with a total length of 501 m. The simulation relies on OMNeT++ and its Veins extension for vehicular networks. We have associated the SUMO simulator to provide these simulation tools with mobility. Figure 4 illustrates how the three parts are designed and work together.

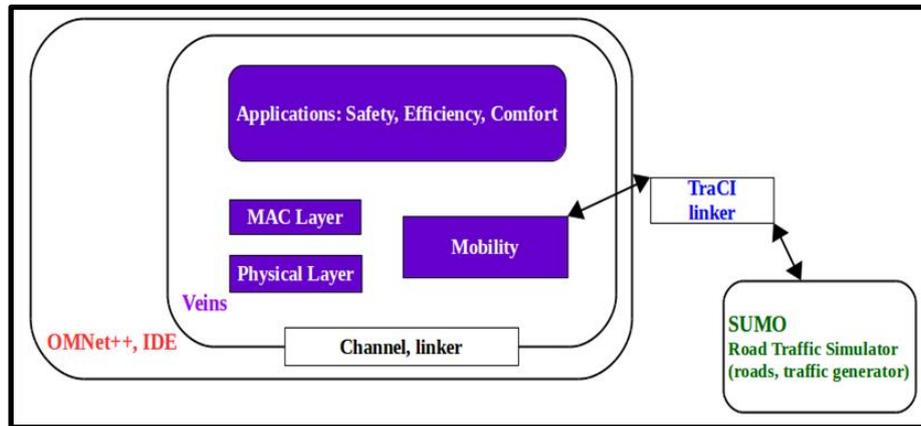


Figure 4: OMNeT++, Veins, SUMO

In fact, OMNeT++ is the general simulation framework, Veins provides the required physical, MAC and application layers, including the WAVE standard and SUMO is used to create the vehicle traffic and to move it along the predefined streets. The integration of SUMO is made into Veins, i.e OMNeT++ framework through a protocol named Traffic Control Interface (TraCI). In fact, each simulation in Veins is performed by executing OMNeT++ and SUMO simulators which are connected via a TCP socket. This allows bidirectionally-coupled simulation of road traffic and network traffic. Movement of vehicles in the road traffic simulator SUMO is reflected as movement of nodes in an OMNeT++ simulation. Nodes can then interact with the running road traffic simulation, e.g., to simulate the influence of IVC on road traffic Veins Community [10].

Table 3: SUMO parameters

Parameters	Comments
Number of vehicles = 50..300 step 50	The number of vehicles
Max. speed of vehicles = 20..70 step 5	The maximum speed of vehicles in a scenario
Min. Gap = 1..20	The minimum distance between two cars

The experiment is characterized by a variable number of vehicles, including. We have gone through three different three scenarios:

- A scenario with a dense traffic that is observed during rush/peak hours. The number of vehicles is above 150 and do not exceed 300 vehicles in the located area;
- A scenario with a sparse traffic that is observed during off-peak hours. Less than 100 vehicles are present in the area;
- A scenario with mid-dense traffic that is observed when there are 100 to 150 vehicles.

3.2. Results and discussion

The results are shown in Figure 5(a), 5(b), 5(c) and 5(d) below.

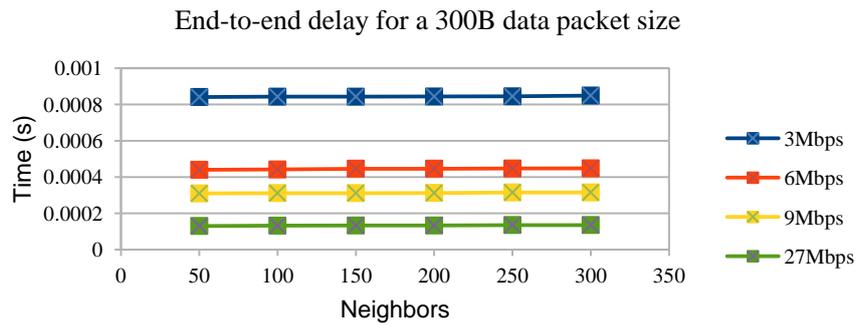


Figure 5(a): End to end delay for a 300 Byte packet size sent at different data rates

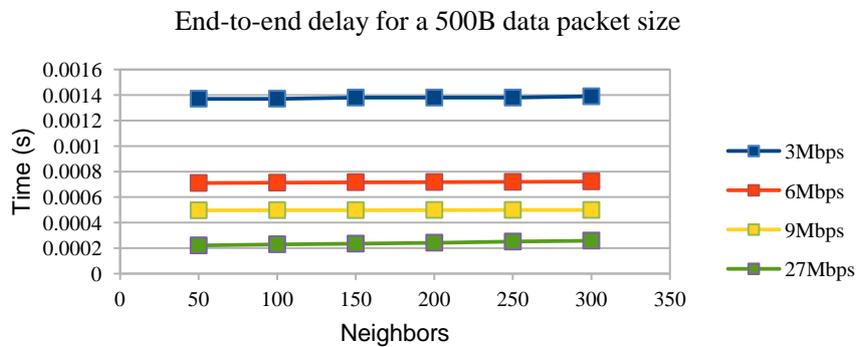


Figure 5(b): End to end delay for a 500 Byte packet size sent at different data rates

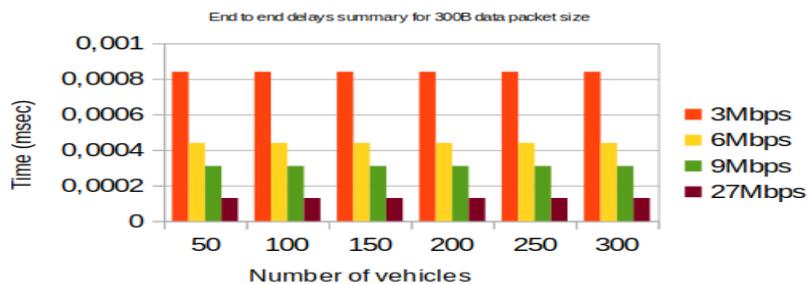


Figure 5(c): End to end delay Summary for a 500 Byte packet size sent at different data rates

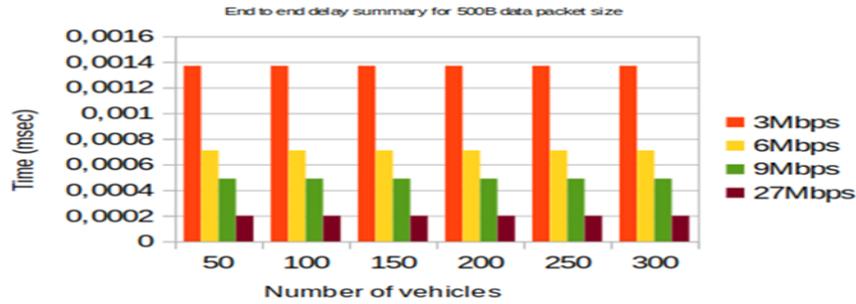


Figure 5(d): End to end delay for a 500 Byte packet size sent at different data rates

These results show latency obtained with the proposed protocol, to send information from the crashed vehicle to the entire neighborhood. Four data rate (bitrates) have been used in the experiment: 3Mbps, 6Mbps, 9Mbps, and 27 Mbps and two data packet sizes: 300 bytes and 500 bytes. The number of vehicles varies from 50 to 300. Independently to the data packet size, we observe that the latency decreases while the data rate increases. The data rate 27 Mbps gives better latency with a value lower than 0,0002 seconds, whereas the throughput 3Mbps gives a latency varying from 0,0008 seconds to 0,0014 seconds. The worst case is even lower than the DSRC allowable latency. In both cases, it is also observed that the variation of the number of vehicles does not greatly impacts the latency. It can be justified by the fact that all the vehicles are located in the same range whether 50 or 300. Variation of size of data packets has a thin impact on the latency. The case with 300 bytes packet outperforms the 500 bytes packet only by a factor less than 60% on average. This result is justified by the fact that the time needed to transmit a packet relies on the size of the packet. The proposed protocol could be efficient in real environment because it could help in warning nearby vehicles that an emergency situation has occurs and this can significantly reduce the rate of emergency situations and the death rate caused by the road accidents. However, there are some limitations. Our results are based on specific path loss which is the simplest one. If another path loss model is considered, results could not be that good.

3.3. Comparison with related work

Table 4: Comparison with related works

Study	Average number of vehicle	Transmission of range	Data packet size	Data rate/Throughput	Latency
Yin and his colleagues (2004)	100	300 meters	100 and 200 Bytes	-	[0.05-0.2]
Dey and his colleagues (2016)	[10-40]	-	250 Bytes	10 MHZ	average 0.068
Paranjothi and his colleagues (2017)	[50-300]	300 meters	256 Bytes	2 Mbps	[0.005-0.009]
Our proposal	[50-300]	300 meters	300 and 500 Bytes	3,6,9,27 Mbps	[0.0002-0.0014]

Table 4 presents a comparison with similar works in terms of latency based on range, data packet size, number of vehicles and transmission range. Table 4 shows that the proposed protocol provides better latency results. It is observed that in case of crashing, the crashed vehicle can take contact with another vehicle for a possible rescue, at least four times quicker than other works. However, experiment conditions in various works are different. For example, in some cases, they deal with obstacles and congestion while in other it is assumed the contrary. This fact shows that the adapted version of DSRC for Cameroon performs well.

4. Conclusion and perspectives

We have modeled and implemented various scenarios of V2V communications using an adapted version of the DSRC protocol to evaluate the end-to-end delays in a typical sub-Saharan city environment. To perform this task, the well-known OMNeT++ network simulator with its vehicular extension Veins coupled with the mobility generator SUMO were used as simulator tools. Our results are satisfactory and they show that our proposal performs very well. Our results even outperform some proposed protocols such as the one proposed by Yin and his colleagues in 2014 [6], Dey and his colleagues in 2016 and even the recent one in 2017 [8] by Paranjothi and his colleagues. In the future, we would like to go beyond the Free Space Path Loss model and focus on the entire physical layer in order to design more realistic scenarios.

5. Limitation and constraints

In order to achieve our goal in this study, we have faced many challenges. First of all, we have struggled a lot to modify the existing version of the DSRC standard as implemented in OMNeT++. This is because we have not been able to reach out the developers in order to understand the whole process. So, we have spent several months in reconstituting all the modules, understand them and finally build our model. We have also faced many problems regarding the system on which simulations were lunched. In fact, the resources were not enough, so we have spent months in running all the simulations, instead of a week with a more powerful system. However, the model is still valid because of the good results we have obtained. Also, this work is limited to environments that are similar to the one described in our experiment, i.e. almost all the cities in the sub-Saharan Africa. Henceforth, it could not behave the same in different environments.

Acknowledgements

This work was done with many aims and the actual paper is one of them. This paper has been entirely read and corrected by Dr-Ing Tchakounte Franklin to whom I would like to express my gratitude.

References

- [1]. K. Watkins (2012), "Safe and sustainable roads: the case for a sustainable development goal" Citeseer. [On-line]. Available: citeseer.ist.psu.edu/
- [2]. Liu, X. & A. Jaekel (2019), "Congestion control in V2V safety communication: Problem, analysis, approaches" *Electronics*. [On-line]. 8(5), pp. 540. Available: www.mdpi.com/2079-9292/8/5/540/pdf [May. 13, 2019]

- [3]. E. C. Eze, S. J. Zhang, E. J. Liu, & J. C. Eze (2016), "Advances in vehicular ad-hoc networks (VANETs): Challenges and road-map for future development" *International Journal of Automation and Computing*. [On-line]. 13(1), pp. 1-18.
- [4]. M. A. Togou, L. Khoukhi and A. Hafid, (2017) "Performance analysis and enhancement of wave for v2v non-safety applications" *IEEE Transactions on Intelligent Transportation Systems*. 19(8), pp. 2603-2614.
- [5]. R. Zhang, F. Schmutz, K. Gerard, A. Pomini, L. Basseto, S. B. Hassen, AIKurtass, I., I. AIKurtass, O. Talabay , A. AlMohanna, S. AlGhamisi, A. A. Biyabani, K. Al-Ghoneim, and O. K. Tonguz, (2018), "Increasing traffic flows with dsrc technology: Field trials and performance evaluation", In *IECON 2018-44th Annual Conference of the IEEE Industrial Electronics Society*, IEEE, pp. 6191-6196.
- [6]. X. Ma, J. Zhang, X. Yin, and K. S. Trivedi, (2011), "Design and analysis of a robust broadcast scheme for VANET safety-related services", *IEEE Transactions on Vehicular Technology*, 61(1), pp. 46- 61.
- [7]. W. Huang, L. Ding, D. Meng, J. N. Hwang, Y. Xu, and W. Zhang, (2018), "QoE-based resource allocation for heterogeneous multi-radio communication in software-defined vehicle networks", *IEEE Access*, 6, pp. 3387-3399.
- [8]. A. Paranjothi, U. Tanik, Y. Wang, and M. S. Khan, (2019), "Hybrid-Vehfog: A robust approach for reliable dissemination of critical messages in connected vehicles," *Transactions on Emerging Telecommunications Technologies*, 30(6).
- [9]. U. A. Khan and S. S. Lee (2019). "Multi-layer problems and solutions in VANETs: A review," *Electronics*, 8(2), pp.204.
- [10]. Veins Community. "Veins Home". Internet: <http://veins.car2.org/>, 2018 [Dec. 27, 2019].