Computer Modelling-Based Optimization of Communication in Warning Applications for VANET

Tibor PETROV[1]

[1] Dept. of Multimedia and Information-Communication Technologies, University of Žilina, Univerzitná 1, 010 26 Žilina, Slovak Republic

tibor.petrov@fel.uniza.sk

Abstract. *Cooperative Intelligent Transport Systems (C-ITS) are one of the key technologies to support intelligent transportation. These technologies, based on Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Anything (V2X) communication are expected to improve road safety significantly. Other benefits include reduced environmental impact, traffic congestions and increased transport efficiency. In this paper, a simple traffic jam warning application is proposed. Warning messages are transferred to vehicles, which form a Vehicular Ad hoc Network (VANET). Communication in the VANET is optimized by means of computer simulation, to achieve minimum RF channel load and end-to-end delay.*

Keywords

Cooperative Intelligent Transport Systems, VANET, computer simulation.

1. Introduction

Cooperative ITS are a promising technology which became a thoroughly studied topic in recent years. There were many projects, studies and field operational test carried out by the research community, automotive industry and standardization authorities.

By statistic means, it was discovered, that 79 % of road traffic accidents are caused by drivers, the rest is caused mainly by pedestrians [1]. So, the vast majority of the accidents are subject to human error. The yearly financial loss caused by deaths and serious injuries at the European road network is estimated at least EUR 100 billion [2]. To reduce these alarming statistics, the European Union set a goal of reducing the number of fatal accidents by half. One of the key contributions to fulfil this commitment can come from deployment of the intelligent transportation systems (ITS). ITS make use of new information and communication technologies to improve the safety, efficiency and convenience of the surface transportation, both for people and for goods [3].

Another key motivation for ITS deployment in the European Union is addressing traffic congestion [4]. Development of these systems is greatly motivated by the need of expanding transportation capacity through the conventional infrastructure. Main ITS tasks are to enhance safety, reduce congestion, decrease environmental impact, improve productivity and energy efficiency [5].

Many of these issues are believed to be solved with the help of C-ITS.

In this paper, a study of impact of Vehicular Ad hoc Network (VANET) on traffic fluency in the city of Žilina is shown. Proposed VANET is used to transfer traffic jam warning messages in a case of traffic accident. Properties of the network and the application feasibility are determined by the means of computer simulation.

2. Communication Technologies for VANETs

There were several communication standards introduced to support wireless RF communication between vehicles and other parts of the ITS system. Many of these use the standardized IEEE 802.11p as their physical layer protocol. Four of the major standards to support vehicular communication are:

- IEEE 1609 Wireless Access in Vehicular Environments (WAVE)
- ETSI ITS
- ISO CALM
- ARIB STD-T109

From the point of view of the ITS components involved in the communication, we can distinguish:

- Vehicle-to-Vehicle (V2V) communication

- Vehicle-to-Infrastructure (V2I) communication
- Vehicle-to-Any other ITS system participant (V2X) communication

In the simulations described further in this paper, a combination of V2V and V2I communication is used and optimized to support a deployment of a traffic jam warning application in the city of Žilina. Simulated VANET uses the IEEE 1609 WAVE protocol for warning messages exchange.

3. Simulation Tools

Vehicular simulation differs greatly from a simulation of static network topologies. VANETs are characterized by a high node velocity, frequent disconnections and specific mobility patterns. Therefore, there are different tools needed to perform realistic simulation of a vehicular communication.

In order to perform simulations described in this paper, there were four tools used in conjunction to achieve realistic simulation results. These were:

- OMNeT++ Discrete event network simulator
- SUMO traffic simulator
- Veins vehicular networks simulation framework
- Custom traffic flow generator for SUMO

The SUMO traffic simulator uses a road network, which was imported from the openstreetmap.org project. This map was converted to XML using SUMO netconvert utility. After that, a stochastic traffic flow, based on data acquired from the Traffic General Plan of Žilina, was generated using our custom traffic generator script written in C++. The SUMO simulator is used to provide a mobility for the discrete event network simulator. However, to make the simulation as realistic as possible, the network and traffic simulators need a mean of bidirectional communication in order to allow dynamic re-routing of vehicles during the simulation. Such an interface is provided by the Veins simulation framework [6]. It uses TraCI (Traffic Control Interface) protocol, which ensures a real-time bidirectional communication between the both simulators via a TCP socket [7]. This feature allows to control the vehicles´ mobility from the network simulation so they can react dynamically according to the information received from other vehicles in the VANET.

In our simulation, this is utilized by re-routing the vehicle flow after an accident happens at intersection.

4. Simulation Scenario

To simulate the application feasibility and its impact on traffic fluency a problematic road segment in the city of Žilina was selected. According to the Traffic General Plan of Žilina [8], approximately 33 170 vehicles a day pass the Košická intersection which is a main node for transport from Czech Republic, Poland and western Slovakia heading to Košice direction. The intersection is well known for frequent collisions and traffic jams caused either by the collisions themselves or by defective traffic lights.

This paper aims to study the impact of C-ITS deployment at this part of Žilina´s road infrastructure.

The simulation starts with a collision near the intersection. Due to the collision, the road segment is blocked and traffic jam starts to form. By using information provided by the VANET and its timely distribution among the nodes in the network, vehicles are able to take a detour instead of being trapped in the congestion as can be seen in the Fig. 1. Vehicles involved in the accident use their onboard units to spread the information about the accident to other traffic participants.

We aim to optimize the communication in order to achieve minimum RF channel load and end-to-end delay of the transferred messages. In terms of delay, there are strict performance requirements that have to be met in order to allow proper application functionality. These requirements are summarized in the Table 1.

Performance class	***Latency [ms]***	***Packet generation frequency [p/s]***	***Communication range [m]***	***Application***
Low latency, high frequency	≤ 100	10-20	≤ 150	Accident, control loss, cooperative collision warning
Medium latency, medium frequency	≤ 200	5-10	≤ 100-130	Intersection collision warning, lane overtake assistance, extended brake signaling
High latency, low frequency	≤ 1000	1-2	≤ 1000	Work zone warning, low bridge warning, road condition warning

Tab. 1. Performance requirements for V2X applications [9].

5. Simulation

In total, there were three simulation scenarios simulated. In the first scenario, only V2V communication was used to spread the warning messages across the network. In the second scenario, a combination of both, the V2V and V2I communication was used. Third scenario uses also a combination of V2V and V2I communication, but this time an optimization was performed to achieve best possible performance.

5.1 V2V Communication Scenario

After the accident had happened, the vehicle involved in the collision started to inform other connected vehicles by broadcasting the warning message. Vehicles in the communication range process the message and broadcast it again. The process repeats virtually endlessly to ensure that all incoming vehicles are informed about the accident. This approach, although simple, is not efficient in terms of RF channel utilization. By flooding the network, many messages are processed redundantly which leads to high channel load and increased end-to-end delay. Many researches, including [10], [11] conclude, that the network easily gets overloaded with increasing number of communicating nodes. Our simulation also supports this fact as can be seen in the Table 2.

5.2 V2V and V2I Communication Scenario

In the second scenario, the warning messages are transferred using a combination of V2V and V2I communication. Network topology includes two roadside units (RSUs). After the accident, involved vehicles broadcast warning messages by the means of V2V communication to their neighbors. These messages are received also by the RSU at Košická, which sends the information to the other RSU near Budatín. The Budatín RSU then starts to periodically transmit the information to inform incoming vehicles. These react by taking a detour, as shown in the Fig. 1. Beaconing frequency of the Budatín RSU was set to 1 Hz, which is a lowest possible beacon generation frequency allowed by the standard.

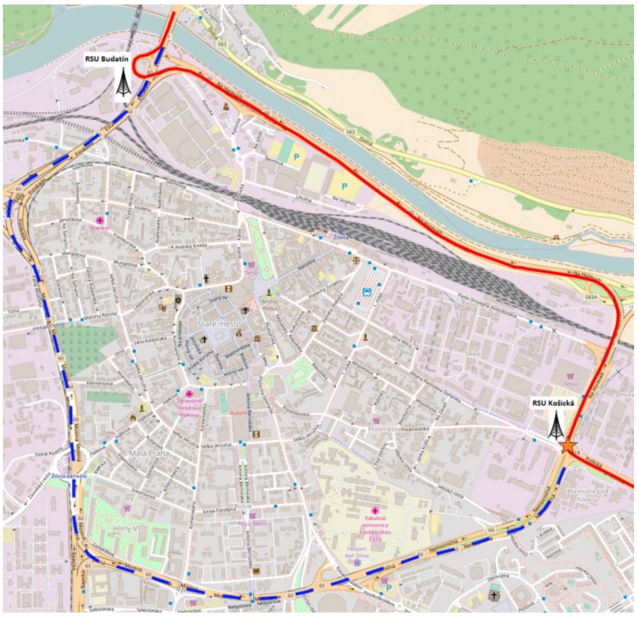

Fig. 1. Simulated network topology and vehicle trajectories. Red line represents the original trajectory, blue line is the detour. Accident site is marked with orange star.

5.3 Optimized V2V and V2I Communication Scenario

This scenario uses also the combination of V2V and V2I communication, but this time, communication rules were slightly optimized to suspend redundant message transmissions. Two additional fields were added to the frame, one describing sender´s identification and one with an application session ID. By this means, it was possible to force certain vehicles to stop transmissions in a certain case. For example, it is irrelevant to send messages to vehicles already trapped in the accident as well as to transmit the same message repeatedly, after the roadside units started periodical beaconing. This transmission redundancy leads to increased channel load, end-to-end delay and computational load of the onboard units in the network.

6. Simulation Results

The results of the three simulated scenarios are summarized in the Table 2.

Figures Fig. 2, Fig. 3 and Fig 4 show the simulated average end-to-end delay of messages transferred via respective communication means. In this case, it can be seen that a combination of V2V and V2I communication seems to be much more effective in all performance parameters than a pure V2V communication. By suppressing redundant message exchange, latency and channel load as well as a device´s computation load was slightly reduced.

We assume that further optimization can be achieved, e.g. by dynamically controlled roadside unit beacon generation frequency. This topic will be a subject to our further research.

6.1 V2V Communication

The first vehicle to react by taking a detour (vehicle #46) got the information 17,42 ms after the accident had happened. The vehicle which had to process the largest number of messages received and sent 9425 WAVE frames during the simulation in order to keep its neighbors informed. Its total busy time was 17,313 seconds. The average busy time of a vehicle in this scenario was 9,629 s. Messages were transferred with an average end-to-end delay of 2,504 ms.

6.2 V2V and V2I Communication

Using the combination of both communication means resulted in significant drop of computation load of devices´ onboard units and end-to-end delay of the transferred messages. The first vehicle to take a detour was the same (#46), but the information spread time was reduced to 16,767 ms. The most loaded onboard unit in the network had to process only 154 messages compared to more than 9000 when using only V2V communication. An average busy time of a device was 0,124 s and an average end-to-end delay of a transferred frame dropped to 1,66 ms.

6.3 Optimized V2V and V2I Communication

When the redundant communication was suppressed a further decrease of the network load parameters could be observed. The most loaded onboard unit processed 144 messages, the information was spread across the network in 16,732 ms and the average end-to-end delay of a frame was decreased to 1,605 ms.

Communication scenario	*V2V*	*V2V & V2I*	*Optimized V2V & V2I*
Maximum messages processed by a vehicle	9425	154	144
Time to spread message across the network [ms]	17,492	16,767	16,732
Maximum busy time of a device [s]	17,313	2,347	1,522
Average busy time of a device [s]	9,629	0,254	0,321
Maximum end-to-end delay [ms]	15,85	14,91	13,98
Average end-to-end-delay [ms]	2,504	1,66	1,605

Tab. 2. Simulation results.

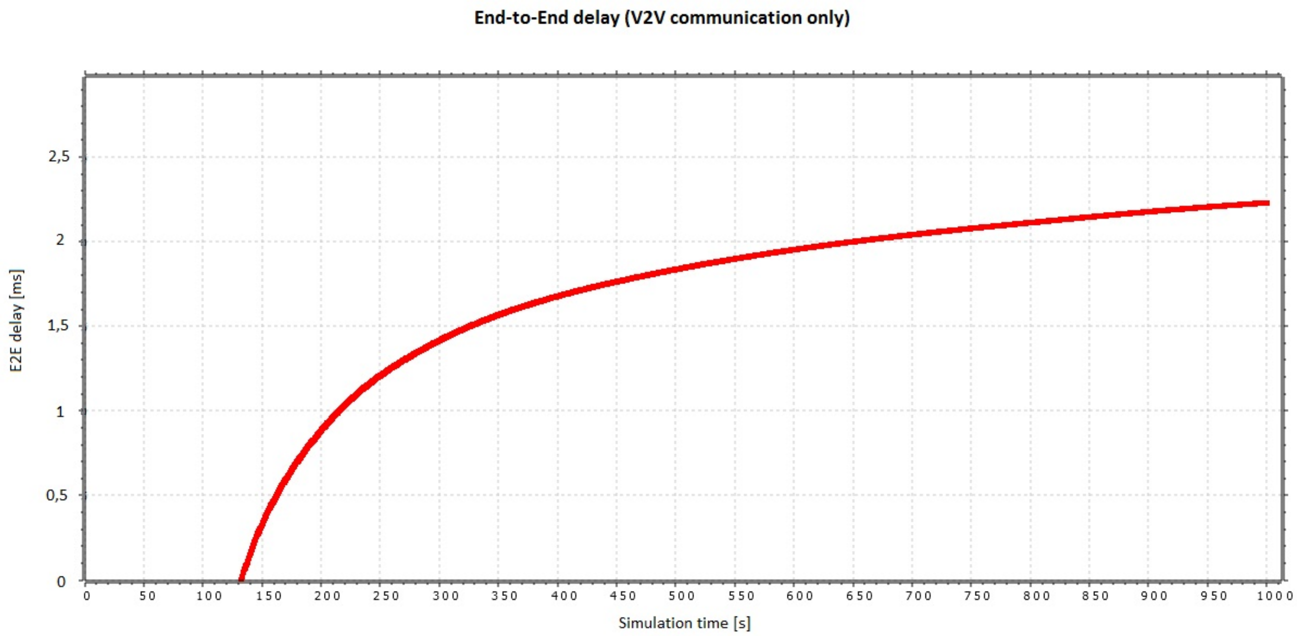

Fig. 2. Average end-to-end delay of messages transmitted using V2V communication.

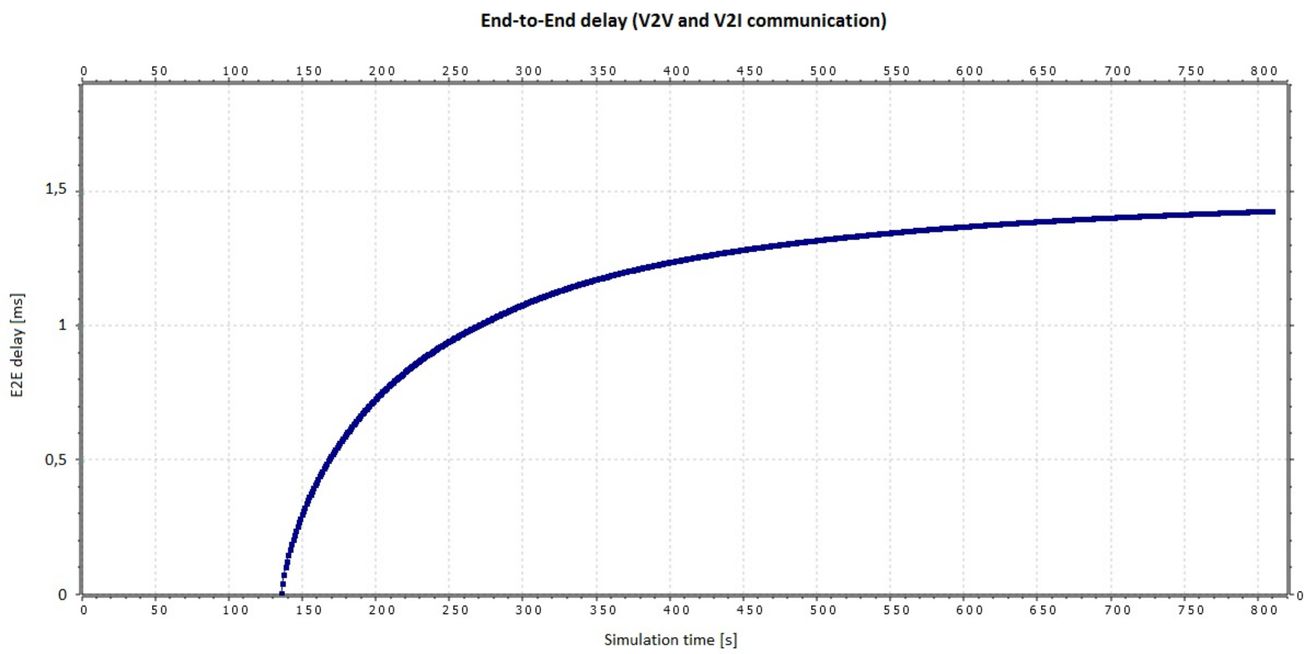

Fig. 3. Average end-to-end delay of messages transmitted using a combination of V2V and V2I communication.

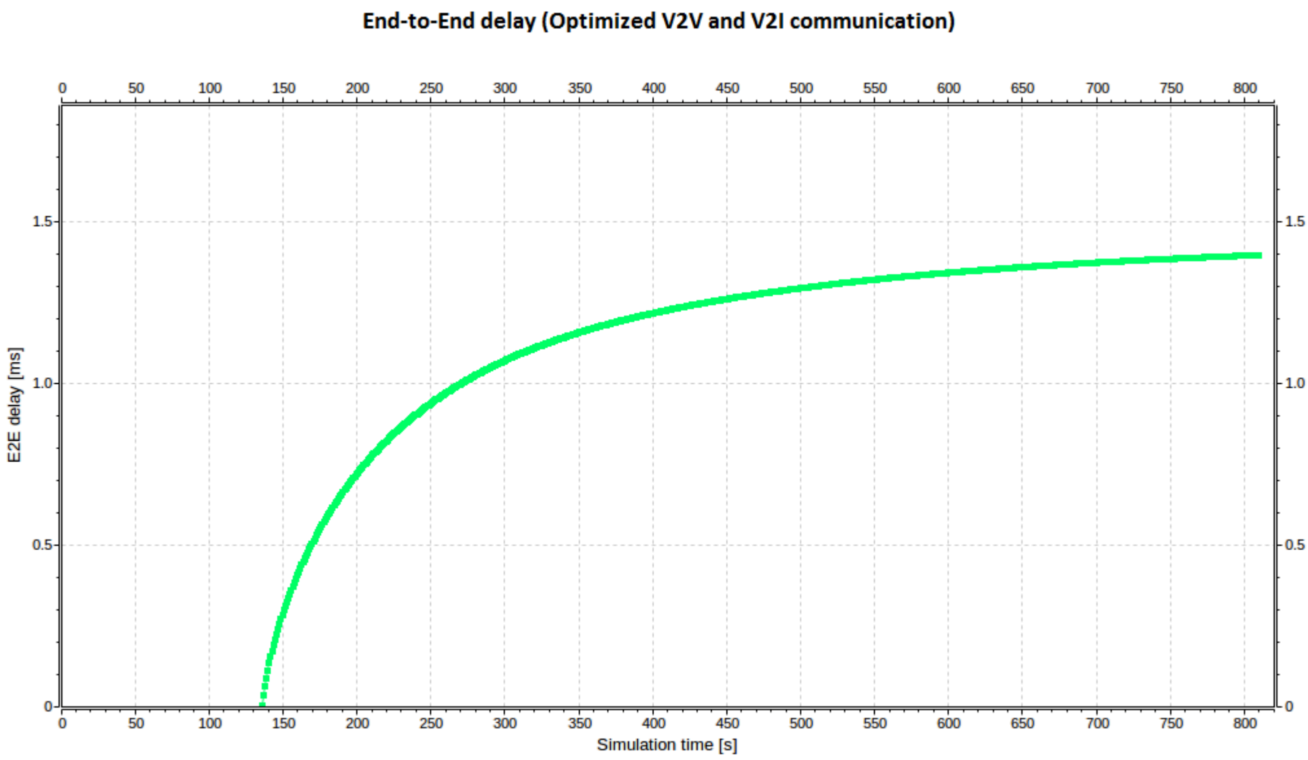

Fig. 4. Average end-to-end delay of messages transmitted using an optimized combination of V2V and V2I communication.

Acknowledgements

This paper was supervised by prof. Ing. M. Dado, PhD., Faculty of Electrical Engineering, University of Žilina. Research described in the paper was supported by the ERAChair Eradiate - Enhancing Research and innovAtion dimension of the University of Žilina in intelligent transport systems, Grant agreement no: 621386, Project 7thFP.

References

[1] EUROPEAN ROAD FEDERATION. Europan Road Statistic 2010.

[2] ESAFETY INITIATIVES [online] , http://www.esafetysupport.info/en/esafety_activities/

[3] WEILAND, R.J., PURSER, L.B. Intelligent Transportation Systems [online], http://onlinepubs.trb.org/onlinepubs/millennium/00058.pdf

[4] EUROPEAN COMMISION. Intelligent transport systems: EU-funded research for efficient, clean and safe road transport, European Union: 2010, ISBN 978-92-79-16401-9

[5] U.S. DEPARTMENT OF TRANSPORTATION. What have we learned about intelligent transportation systems? December 2010

[6] Veins: The open source vehicular network simulation framework [online], http://veins.car2x.org/documentation/modules/

[7] BIALON, R. Coupled simulation of road traffic, V2X-applications and V2X-communication via mobile cellular networks. Master´s Thesis, Heinrich-Heine-Universität Düsseldorf, 2015.

[8] Územný general dopravy Mesta Žilina [online], http://enviroportal.sk/sk/eia/detail/uzemny-generel-dopravy-mesta-zilina

[9] OH, S., GRUTESER, M., POMPILI, D. Coordination-free Safety Messages Dissemination Protocol for Vehicular Network. IEEE Transactions on Vehicular Technology, Volume PP, Issue 99, 2012.

[10] VINEL, A. 3GPP LTE Versus IEEE 802.11p/WAVE: Which Technology is Able to Support Cooperative Vehicular Safety Applications? IEEE Wireless Communications Letters, vol.1, no.2, pp. 125-128, 2012.

[11] HARDING, J., POWELL, G.R., YOON, R., FIKENTSCHER, J., DOYLE, C., SADE, D., LUKUC, M., SIMONS, J., WANG, J. Vehicle-to-vehicle communications: Readiness of V2V technology for application. (Report No. DOT HS 812 014). Washington, DC: National Highway Traffic Safety Administration, August 2014.

About Authors...

Tibor PETROV was born in Plovdiv, Bulgaria in 1990. In 2015 he finished MSc at the University of Žilina, Faculty of Electrical Engineering, Department of Telecommunications and Multimedia. Currently he studies doctoral degree at the same department. His research activities include wireless networks and cooperative technologies in the Intelligent Transportation Systems (ITS) environment.