Study of Performance of the Vehicular Ad Hoc Networks in Dense Network Scenarios

Tibor Petrov[1](✉), Viktor Ďurček[1], Milan Dado[1],
and Karl Ernst Ambrosch[2]

[1] Department of Multimedia and Information-Communication Technologies,
Faculty of Electrical Engineering, University of Žilina,
Univerzitná 8215/1, 010 26 Žilina, Slovakia
`tibor.petrov@fel.uniza.sk`
[2] University Science Park, University of Žilina,
Univerzitná 8215/1, 010 26 Žilina, Slovakia

Abstract. Vehicular Ad hoc Networks (VANETs) became a thoroughly studied topic in the last years both by the academic community as well as by the automotive industry stakeholders. Because of their potential to save lives, make the transport more efficient and green, it is very important to understand their specific behavior and to resolve their known issues. This paper aims to study the performance of the VANETs in a very dense traffic conditions by the means of a computer modelling. The scenario in these simulations was deliberately chosen to represent the worst possible communication cases. Even though the communication in such extreme conditions is unlikely to occur in real-life situations, it is vital to find out, where are the communication limits of the VANETs.

Keywords: VANET · Vehicular communication · V2V · V2I
Computer modelling · Simulation

1 Introduction

Vehicular networks are expected to bring many benefits into the field of transportation. Since the messages carried by these networks can often be of safety-related nature, it is absolutely vital to find out the network performance limits. The field testing in real-life traffic is difficult because of safety concerns. Nowadays, a computer simulation can be used to successfully study the performance of vehicular networks. In this paper we aim to study the performance of the IEEE 802.11p Vehicular Ad hoc Networks under extreme traffic density conditions. Simulations were carried out by the Riverbed Modeler simulation software.

2 Channel Coding in VANETs

The IEEE 802.11p physical layer is based on OFDM with 64 subcarriers. The 10 MHz channel bandwidth is divided into 52 orthogonal subcarriers with different frequencies. Four of the subcarriers are used for pilot signals and 48 subcarrier frequencies are used

T. Kováčiková et al. (Eds.): INTSYS 2017, LNICST 222, pp. 85–89, 2018.
https://doi.org/10.1007/978-3-319-93710-6_10

for data transmissions. Subcarriers are modulated using BPSK, QPSK, 16QAM or 32QAM to provide data rates from 3 to 27 Mbit/s [1].

IEEE 802.11p uses convolutional forward error correction coding with 1/2, 2/3 or 3/4 coding rate. Data rates, used modulation and coding rates can be seen in the Table 1.

Table 1. IEEE 802.11p modulation schemes and data rates [1].

Modulation type	BPSK		QPSK		16-QAM		32-QAM	
Coding rate	1/2	3/4	1/2	3/4	1/2	3/4	2/3	3/4
Coded bit rate [Mbit/s]	6		12		24		36	
Data rate [Mbit/s]	3	4,5	6	9	12	18	24	27
Data bits per OFDM symbol	24	36	48	72	96	144	192	216

3 Simulation Parameters

Simulation was carried out by the Riverbed Modeler discrete event network simulator. A simulation model was built in order to maximally follow the precise specification of the IEEE 802.11p amendment physical layer (PHY) and MAC.

3.1 Simulation Scenario

Simulation scenario consists of a various number of communication module-equipped vehicles waiting at the intersection of three road segments in an urban environment. It represents a typical case of a traffic jam forming in a large city. Vehicles, which join the ad hoc communication network are moving very slowly and often stop. The number of vehicles at the intersection increases as the incoming traffic flow is of higher intensity than the flow of vehicles leaving the intersection.

At the intersection, there is a fixed roadside unit (RSU) present. This node is equipped by the same wireless communication technology as the vehicles at the intersection but does not generate any data or retransmits the frames received by the vehicles. It acts as a reference point against which the delays and signal to noise ratio are measured.

The simulation was run for a number of vehicles ranging from three up to 600. The upper limit of vehicles was selected based on the physical layer's estimated maximum communication range, assuming minimal possible spacing between vehicles trapped in the traffic jam and thus should represent the worst possible scenario for vehicular communication.

3.2 Model Parameters

In order to obtain as authentic results as possible, the simulation model parameters were set to comply with the PHY and MAC specifications of the IEEE 802.11p.

Radio Channel Parameters. Simulations were carried out using the European radio channel frequency allocations. For road safety applications, the frequency band from 5 875 to 5 905 MHz was allocated by the ECC Decision (08)01 in March 2008 [2]. Table 2. shows the nominal carrier frequency allocations as stated in [3].

Table 2. ETSI ITS nominal carrier frequency allocations [3].

Channel name	Carrier centre frequency (MHz)	Maximum channel bandwidth (MHz)
G5-SCH4	5860	10
G5-SCH3	5870	10
G5-SCH1	5880	10
G5-SCH2	5890	10
G5-CCH	5900	10
G5-SCH5	5910	10
G5-SCH6	5920	10

In order to simulate the worst possible case, all the beacons transmitted by the vehicles were considered to be safety-related. In this case, the Control Channel (CCH) at the 5900 MHz frequency was used for all the transmissions.

Access Layer Parameters. Simulations were performed using CCH's default 6 Mbit/s data rate. Transmit power was set to a maximum limit of 33 dBm according to the [4]. In the Riverbed Modeler, physical layer characteristics parameter was set to OFDM (802.11a) as this is the closest physical layer model to the IEEE 802.11p used in vehicular networks. Channel bandwidth was adapted accordingly.

EDCA Parameters. The IEEE 802.11p's MAC layer uses Enhanced Distributed Channel Access (EDCA) to provide contention-based differentiation between packets with different priorities [5]. EDCA, based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) defines four Access Categories (ACs), which are used to transfer data of different priorities, introducing QoS in the vehicular networks.

4 Simulation Results

The proposed simulation scenario was simulated for a varying number of vehicles ranging from three up to 600. There were five statistics collected from the simulation: Signal to noise ratio relative to the RSU, wireless channel load, throughput, utilization and medium access delay (MAD). Figures 1 and 2 show the simulated parameters' values for a various number of vehicles.

With the increasing number of vehicles in the communication range, the MAD parameter rapidly increases up to a point where collisions start to occur at the medium access layer. When the number of vehicles in the network is so high, that collisions are very frequent (more than 100 vehicles in the communication range), the medium access delay starts to asymptotically approach it's maximum value. At this point, the network is congested and cannot support any additional communication demands.

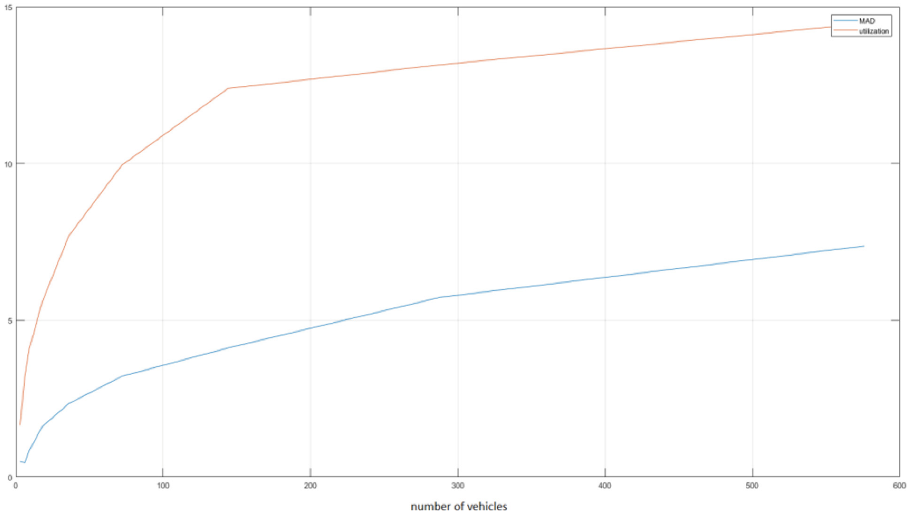

Fig. 1. Wireless channel medium access delay in ms and utilization in %.

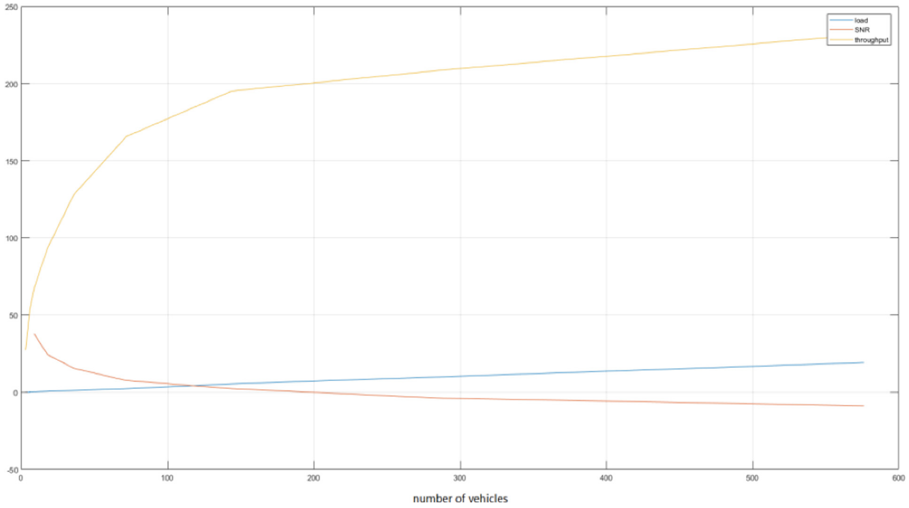

Fig. 2. Wireless channel load in Mbit/s, RSU signal-to-noise ratio in dBm and radio receiver throughput in kbit/s.

The SNR parameter, naturally, drops significantly with the increasing number of vehicles in the network. If the transmit power is not dynamically controlled, it can even reach negative values for a high number of transmitting vehicles (more than 100 vehicles in the carrier sense range). The transmission bit error rate increases significantly and the convolutional FEC code is unable to correct the transmission errors.

5 Conclusion

Totally, there were 10 simulations performed. Presented results represents the average values of the simulated characteristics. From the results, it becomes clear, that it is very important to include a transmission power control mechanism in a Vehicular Ad hoc Network. Due to the interference between the network nodes in very dense networks the SNR drops significantly and can even achieve negative values so the convolutional forward error correction code is unable to compensate the high bit error rate. Taking in account this point of view, the use of LDPC codes can be considered for their favorable performance in low SNR scenarios [6].

Acknowledgements. Research described in the paper was supported by the ERAChair Eradiate - Enhancing Research and innovation dimension of the University of Zilina in intelligent transport systems, Grant agreement no: 621386, Project 7thFP.

References

1. Abdelgader, A.M.S., Lenan, W.: The physical layer of the IEEE 802.11p WAVE communication standard: the specifications and challenges. In: Proceedings of the World Congress on Engineering and Computer Science 2014, vol. II. Newswood Limited (2014)
2. ECC Decision (08)01: ECC Decision of 14 March 2008 on the harmonized use of the 5875–5925 frequency band for Intelligent Transport Systems (ITS)
3. ETSI: Draft ETSI EN 302 571, Intelligent Transport Systems; Radiocommunications equipment operating in the 5855 MHz to 5925 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive
4. ETSI: Technical Specification ETSI TS 102 687, Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part
5. Sun, W., Zhang, H., Pan, C., Yang, J.: Analytical study of the IEEE 802.11p EDCA mechanism. In: Intelligent Vehicles Symposium (IV). IEEE (2013)
6. Purkovic, A., Burns, N., Sukobok, S., Demirekler, D.: LDPC vs. Convolutional Codes for 802.11n Applications: Performance Comparison. IEEE (2004)