

# IEEE 802.11n Evaluation in Vehicular Communication Systems

J.Jansons

*Abstract - In this paper is presented the model of wireless base station goodput evaluation. There was used wireless access point model as a queuing system with different kind of requests and cyclic auto traffic model. Wireless mobile networks have different parameters, such as client stations distance to access point, number of clients in wireless network range, vehicle speed and traffic type. These parameters were analyzed and presented in this paper.*

*Keywords: Short Range Vehicle Network; 802.11n; wireless network; goodput; network performance; transport; mobile stations; auto traffic; vehicle speed; Markov chain.*

## I. INTRODUCTION.

The need for reduction of highway vehicular accidents, traffic congestions, transportation time, fuel consumption and environmental impact of road transport are serious change for both academics and industry. Researchers in both sides are greatly interested to develop vehicular communication and networking technology in two realistic ways vehicle to vehicle (V2V) in ad hoc mode and vehicle to infrastructure (V2I) with fixed nodes along the road. The potency to exchange information wirelessly V2X is a foundation stone for building powerful Intelligent Transport Systems (ITS). In Europe, USA and Japan are great efforts made from automakers and governments to reach single standards through the several and common projects such as CAR 2 CAR Communication Consortium, Vehicle Safety Communication Consortium, EUCAR SGA etc. Result from common effort is an international standard, IEEE802.11p [1], also known as Wireless Access for Vehicular Environments (WAVE), which was published in July 15, 2010. This standard will be used as the groundwork for Dedicated Short Range Communications (DSRC). This type of communication has potential to improve safety on the road, traffic flow and provide comfort for passengers and drivers with expedite applications such as INTERNET, network games, automatic electronic toll collection, drive-through payments, digital map update, wireless diagnostic and flashing etc. DSRC is the one step in the future, because it lets inter-vehicular and vehicle to infrastructure communication wirelessly.

Wireless networking based on IEEE802.11 technology [2] has recently become popular and broadly available at low-cost for home networking and free Wi-Fi or commercial hotspots. DSRC starting idea was to equip vehicular network nodes with off-the-shelf wireless technology such as IEEE802.11a. This technology is cost effective and has potential to grow and new versions were recently produced. The latest standard of wireless local area network (WLAN) is IEEE802.11n[3]. The IEEE 802.11n standard promises to improve and extend most

popular WLAN standards by significant increasing throughput, reliability and reach.

Nowadays dispositions of WLAN-based access technology are predominate to stationer indoor and outdoor users who are most slowly moving and in range limited. Despite the fact that the standard has been developed not for fast dynamic usage, nothing limits it to be evaluating for vehicular communication systems. Motivation is to understand the interaction between the vehicle speed and goodput of WLAN-based network.

Realizing field trials for goodput evaluation of vehicular wireless communication systems is very difficult and costly because many vehicles and communication equipments need to be purchased or rented, and also many experimenters need to be employed. Given such problems, it is highly desirable to obtain mathematical description of process with real data from small scale scenarios of practical measurement results and perform evaluations prior conducting field trials as it is made in this work.

This paper is constructed as follows: After introduction the problem in Section 1, Section 2 provides some information about related work. Then, in Section 3 and 4 provides some background issue about the vehicular traffic and IEEE802.11n WLAN performance evolution practical results, respectively. After then, in Section 5 describes a queuing model of V2I communication with one wireless access point and variable amount of mobile clients (vehicles). After demonstrating the analysis results in Section 6. Section 7 summarize and concludes this paper with a brief description on future works.

## II. RELATED WORK

Important researching object of vehicular networks is the performance of wireless communication technology in various vehicular mobility scenarios. Analyses of vehicular network communication performance have been comprehensively disclosed in different author's papers. Researchers and industry have made much effort to develop the practical tests platform and took long time to evaluate vehicular communication and networking technology.

J. P.Singh et al [4] have assessed the performance of WLAN based on IEEE 802.11b compliant equipment with various vehicular traffic and mobility scenarios. They have observed degradation of network throughput and the quality of wireless communication link in three different scenarios – suburban, urban and freeway, what corresponds to vehicle speed limits - 40 mph, 25 mph and 65 mph accordingly.

Ott and Kushner [5] have introduced the idea of Drive-thru Internet: the use of WLAN technology (IEEE802.11b) to

provide access for users travelling by one car, particularly on highways (V2I solution). They have measured and analyzed transmission between a car with external antenna and a fixed access point comparing UDP and TCP protocols. In their experimental tests they have managed to provide connectivity and data transmission even at speed 180 km/h.

Gass et al [6] have used similar scenario and they have performed measurements in desert without additional signal interference. In the test car speeds vary from 8 to 120 km/h and they have shown that data transmission between car and access point is depending from the car speed.

Wellens et al [7] have realized data transmission between two cars using infrastructure mode. Results show that the goodput is dependent from the distance between the cars, the visibility and the rate adaptation algorithm, and less dependent from the speed of cars.

Contra Wellens observation Rubinstein et al [8] have realized similar experiment like Wellens et al, but using ad hoc mode without external antennas and in-car to in-car networking. They found that the car speed is directly related to the data transmission. They also considered newest wireless communications technology (IEEE802.11g) is more fit for vehicular networking than IEEE802.11a.

### III. MODELLING VEHICULAR MOBILITY

The mobility model that will be utilized in the remainder of this paper is introduced briefly in this section.

In general, traffic engineers distinguish two major classes of mobility models which have both spatial extension and temporal duration of traffic flow.

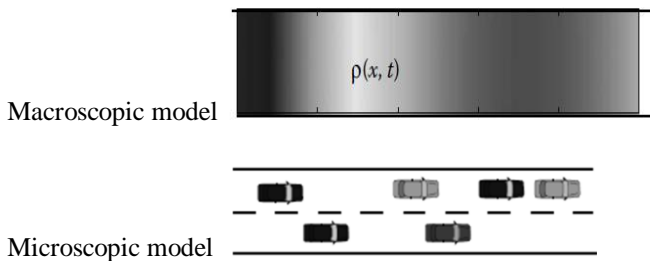


Fig.1. Illustration of two main traffic modeling options: a snapshot of a road at time  $t$  is either described by macroscopic traffic magnitude like traffic density  $\rho(x, t)$  or microscopic traffic magnitude like a position  $x_i(t)$  and speed  $v_i(t)$  of  $i$  vehicle which behavior is currently under investigation.

Macroscopic traffic flow models describe the vehicular mobility as a hydrodynamic phenomenon or a physical flow of some fluid. These models aggregate three variables like the traffic density (vehicles per kilometer), traffic flow (vehicles per hour) and velocity (kilometer per hour) as a function of time and space. This analogy between traffic flows and the fluid flows was initially used by Lighthill, Whitham and Richard (LWR) model [9-10]. The LWR model equation (1) was expressed as law of conservation of vehicles in traffic:

$$\frac{l(x)d\rho(x,t)}{dt} + \frac{dQ(x,t)}{dx} = 0, \quad (1)$$

where  $l(x)$  is the number of lanes at location  $x$ ,  $\rho(x,t)$  is a traffic density in vehicle per lane per kilometer at time  $t$  and location  $x$  and  $Q(x,t)$  is a traffic flow in vehicles per hour at location  $x$  at time  $t$ . Advanced models of LWR additional provide the macroscopic velocity as fluent although to reflect on the finite acceleration potency of vehicles [11-12].

By way of contrast, microscopic traffic models describe the motion of each individual vehicle. In few research papers [13–16] are discussed different microscopic traffic models in terms of their analytical description and verified their realism. Based on those studies, car-following models are the appropriated approach for studies of vehicular networks. Car-following models describe the behavior of each driver in relation to the vehicle ahead so called the leading vehicle.

A microscopic traffic model from Treiber et al. [16], called Intelligent Driver Model (IDM) belongs to the type of deterministic car-following models, which is based on follow-the-leader concept. This model shows a plausible mobility behavior of single driver through the instantaneous acceleration of  $i$  vehicle obtained from the following equations:

$$\frac{dv_i(t)}{dt} = \alpha \left[ 1 - \left( \frac{v_i(t)}{v_{max}} \right)^4 - \left( \frac{\delta}{\Delta x_i(t)} \right)^2 \right] \quad (2)$$

$$\delta = \Delta x_{min} + \left[ v_i(t) \cdot T + \frac{v_i(t) \cdot (v_{i+1}(t) - v_i(t))}{2\sqrt{\alpha \cdot \beta}} \right] \quad (3)$$

with the following set of notation:

- $\alpha$  – acceleration;
- $\beta$  – deceleration;
- $T$  - safe time gap;
- $\Delta x_{min}$  - minimum safety distance;
- $\Delta x_i(t)$  - distance between the  $i$  and  $i+1$  vehicle;
- $v_{max}$  - maximum desired speed;
- $\delta$  - desired dynamical distance.

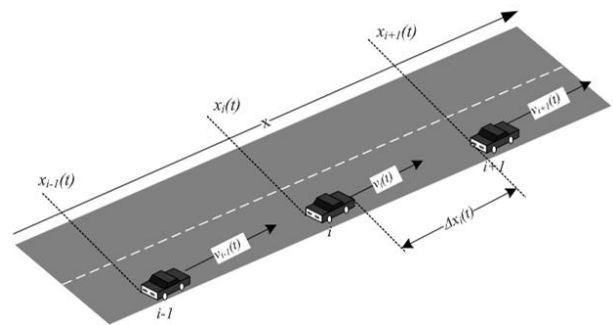


Fig.2. Microscopic traffic notation.

Index  $i+1$  describe the ahead vehicle, which is located at  $x_{i+1}(t)$ , and travels at velocity  $v_{i+1}(t)$ , at time  $t$  as shown in Figure 2.

TABLE 1  
PARAMETERS OF IDM TOGETHER WITH REASONABLE SETTING  
RANGE FOR DIFFERENT DRIVING SCENARIOS

Intelligent Driver Model parameters	Reasonable setting range
$v$ (m/s)	14 - 55
$\alpha$ (m/s <sup>2</sup> )	0.3 - 3
$\beta$ (m/s <sup>2</sup> )	0.5 - 3
T (s)	0.5 - 9

Working out with defined parameters and simplified IDM was achieved that the traffic density vs. speed relations can be approximated as follow:

$$\rho(v) \approx \frac{d}{(l+s_0)} \cdot e^{-0.0349v} \quad (4)$$

where

- $s_0$  – minimum traffic congestion distance (m);
- $l$  – average vehicle length (m) ~ 4.12 meter;
- $d$  – WLAN access point production phase or a certain window of useful connectivity distance during which effective communication can be taken place;
- $v$  – balanced speed of vehicles.

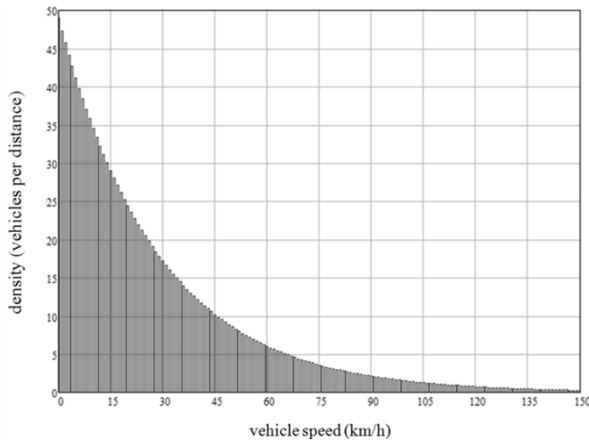


Fig.3. Approximated velocity-density relation of the IDM.

The traffic density properties depend on minimum traffic congestion distance (here set to 2 meter) and desired velocity (here illustrated for 150 km/h).

Starting from such setting, the focus of this paper is to evaluate the goodput of wireless network access point under variable number of vehicles, which vary according to vehicles traffic model.

However, vehicular traffic is an extremely complex dynamic process due to nonlinear interactions between travel decision behavior, routing of vehicles in a traffic network and traffic congestion occurrence within the network [13]. Finally one can be use (4) relationship for analyses of wireless communication performance with finite customer quantity  $N(v)$ , which can be mapped into Markov birth-death system.

#### IV. IEEE802.11n WLANs

Evaluations of a low-cost WLAN in different scenarios are currently a topic research area in academia and industry [9-11]. Remarkable efforts in the research field are achieved to provide comprehensive tests results which are off-the-shelf technologies mostly based on the widely deployed IEEE 802.11a/b/g standards.

The main contributions of this section are to give an overview on the latest standard like IEEE802.11n improvements and experimental results from trial tests. The field test was performed in absence of other conventional wireless signals in order to be able to perform WLAN root cause analysis in mobile environment.

##### A. IEEE802.11n improvements

The significant improvement of 802.11n standards comparing to previous standards is the raw data rate of the wireless channel up to 600 Mbps – more than ten-fold improvement over 54 Mbps of IEEE802.11 a/g maximum data speed. Table 2 shows the maximal data rate of the standard. This capacity has been gained through different features.

At the Physical (PHY) layer of the standard is applied the multiple antennas at the receiver and transmitter, called MIMO (Multiple Input Multiple Output) together with signal processing and the use spatial division multiplexing (SDM) at a channel width of 40MHz. At the sub-layer of Data Link layer, Medium Access Control (MAC) data communication protocol extensions like Frame Aggregation (FA) and Block Acknowledgement (BACK).



Fig.4. Multiple Input Multiple Output.

At the PHY layer, the main advantage is the capability to transmit and/or receive coincidentally from multiple antennas which offer spatial diversity improving the reliability of wireless connection through the space-time block coding (STBC). This coding method reduces the error rate in environments with presence of high radio frequency interference and distortion. High data rate is obtained not only with multiple data stream through various (up to four) antennas but also with extended modulation and coding rate schemes (MCS). The selection of a given radio frequency modulations (RF), OFDM guard interval (GI) and coding rate are represented by MCS index value from 0 to 31.

TABLE 2  
SOME VARIABLES OPTIONS OF IEEE802.11N STANDARD  
CORRESPOND TO RAW DATA RATE

MCS index	Stream	Primary modulation type	Coding rate	Raw data rate (Mbps)			
				20MHz		40MHz	
				OFDM guard interval ( $\mu$ s)			
				0.4	0.8	0.4	0.8
0	1	BPSK	1/2	7.2	6.5	15	13.5
1	1	QPSK	1/2	14.4	13	30	27
--	--	--	--	--	--	--	--
13	2	64QAM	2/3	115.6	104	240	216
--	--	--	--	--	--	--	--
15	2	64QAM	5/6	144.4	130	300	270
--	--	--	--	--	--	--	--
20	3	16QAM	3/4	130.7	117	270	243
--	--	--	--	--	--	--	--
31	4	64QAM	5/6	288.8	260	600	540

At the MAC layer, FA is the way to reduce the MAC protocol overhead from 84% to 14% by transmitting multiple PHY frames. Frame aggregation or payload optimization is method of bundling multiple frames together to reduce the preambles and inter-frames spacing thus increasing the application level data rate or goodput. In the standard are defined two methods of frame aggregation: MAC Service Data Unit Aggregation (A-MSDU) and MAC Protocol Data Unit Aggregation (A-MPDU). In 802.11a/g the maximum payload per single MAC frame cannot be more than 2304 Bytes but in 802.11n it is possible using A-MSDU up to 7935 Bytes and A-MPDU 65535 Bytes.

TABLE 3  
IEEE802.11 N STANDARD RELATIONSHIP RAW DATA  
THROUGHPUT IN SEQUENCE

Description of improvements in sequence	Data rate up to (Mbps)
IEEE802.11n legacy mode	54
Increasing useful number of OFDM subcarriers from 48 to 52	58.5
Additional coding rate (5/6)	65
Reducing OFDM symbol guard interval from 0.8 $\mu$ s to 0.4 $\mu$ s	72.2
Doubling channel bandwidth from 20MHz to 40MHz	150
MIMO option	600

### B. Measurement tools and scenarios

There are only a few numbers of paper [16–19] providing analyses of vehicular network similar to this one. The main goal of practical test is to investigate the possibility of 802.11n standard in vehicular to infrastructure mode using cost effective and off-the-shelf equipments, and available software. In order to reach the aim has been performed set of measurements with one access point (AP) and a mobile user's device which was located in a moving vehicle at a constant speed of 20 kilometer per hour (kmph), 40 kmph, 60 kmph, 80 kmph and 100 kmph. The constant vehicle speed has been maintained using cruise control.

The access point has been directly connected to the fixed station. Off-the-shelf laptop with WLAN based on IEEE802.11n standard was used as mobile user's device without external antenna and the similar laptop for fixed station is wired to an off-the-shelf WLAN AP (ASUS RT-N16). This multi-functional Gigabit wireless N router is an cost effective AP supporting 802.11n standard draft data rate up to 300 Mbps and operating licenses free frequency band (2.4 GHz) and has a transmit power rating at 15.8~19.5dBm. The network topology and system configuration depict in Figure 5.

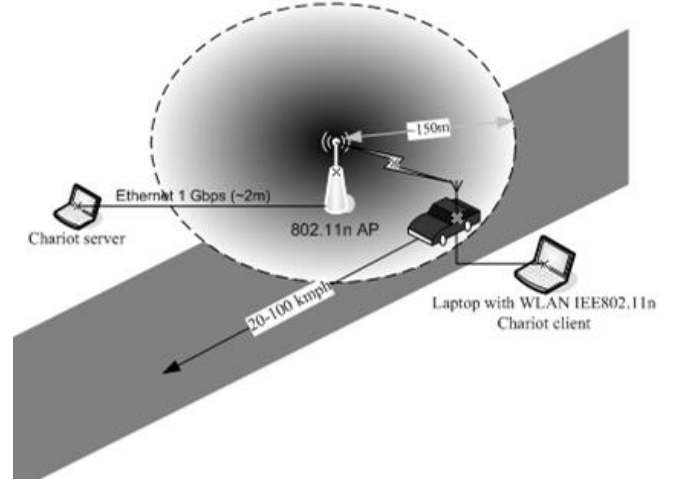


Fig.5. Field trial measurement test setup – V2I scenario.

The access point has been directly connected to the fixed station. Off-the-shelf laptop with WLAN based on IEEE802.11n standard was used as mobile user's device without external antenna and the similar laptop for fixed station is wired to an off-the-shelf WLAN AP (ASUS RT-N16). This multi-functional Gigabit wireless N router is an cost effective AP supporting 802.11n standard draft data rate up to 300 Mbps and operating licenses free frequency band (2.4 GHz) and has a transmit power rating at 15.8~19.5dBm. The network topology and system configuration depict in Figure 5.

TABLE 4  
EXPERIMENTAL SETUP

Item	Setting
Wireless technology	802.11n only
Channel	fixed
Channel wide	20MHz
Frequency band	2.4GHz
Tx power	17mW
Maximal data rate	up to 130 Mbps
MIMO Transmission fixed rate	Auto
OFDM Guard Interval	0.8 $\mu$ s
Preamble	Long
Size of sending file	100000 Bytes
Transport protocol	TCP
IP address	Fixed
Velocity	20/40/60/80/100 kmph

For establish wireless connectivity quickly, the AP and the mobile user's device WLAN adapter were configured to

use the same frequency channel and ESSID, the encryption has been deactivated. IP addresses for all connections have been entered in prior do to highly variable performance.

The network throughput was taken to estimate the TCP performance. For this have been used a client and a server of The IxChariot program (Version 6.7) with the client residing on the mobile user's device, i.e., in vehicle and server running on a fixed station with Ethernet based connection to AP router interface. By entering a WLAN AP zone, client connected to server and initiated a data exchange according to prior configuration.

Main measurement setup parameters are summarized in Table 4.

Additional for continues power supply, two BACK-UPS CS 500 were used for providing the power supply to AP and fixed station.



Fig.6. Map view and photo from the experiment location

The throughput of WLANs depends heavily on the environment, including the distance between the client and the access point. The throughput generally falls off as distance increases, but obstacles and signal interference from different signal sources also have a significant effect. Therefore, prior to the test was conducted a scanning of existing access points that could interfere with testing signals. No others wireless networks operators in this area, except some wiki signal components from other channel in the end of the test bed. At the starting point the car was out

of range of access point.

Moreover the test bed was chosen carefully without objects in the line of sight. As shown in Figure 6, the field trial was deployed over a straight and 1400m long runway of airfield "Rumbula" not far from Riga, the capital city of Latvia.

During the trial test was performed a total of 16 runs. Each configuration was tested more the twice, to get better results.

### C. TCP measurement results

The results of the outdoor performance test for IEEE802.11n WLAN at various speeds of vehicle is shown Figure 7 (a-b). The throughput is plotted versus elapsed time by different velocity of the car. The figures show that the throughput is increasing by approaching the access point contrary while moving away is decreasing due to the adaptive data rate. The access point adaptive data rate which impact of the subsequently uses of different primary modulation type received by the testing car is dependent on its distance (here expressed in elapsed time) from the access point. The throughputs have floating effect which can be also explained by variations of channel conditions due to fading.

Table 5 depicts a certain window of useful connectivity and successful file retransmission quantity. As shown in this Table, the average useful connectivity window or contact time is about 77 seconds at 20 km/h. The useful connectivity window decrease proportional by increasing the velocity of speed. The peak transferred file rate is value of 1440 obtained by slow movement. When the speed of car were increase to 100 kmph, IEEE802.11 n technology still allows to transfer 324 times 100 000 bytes large file during connectivity windows.

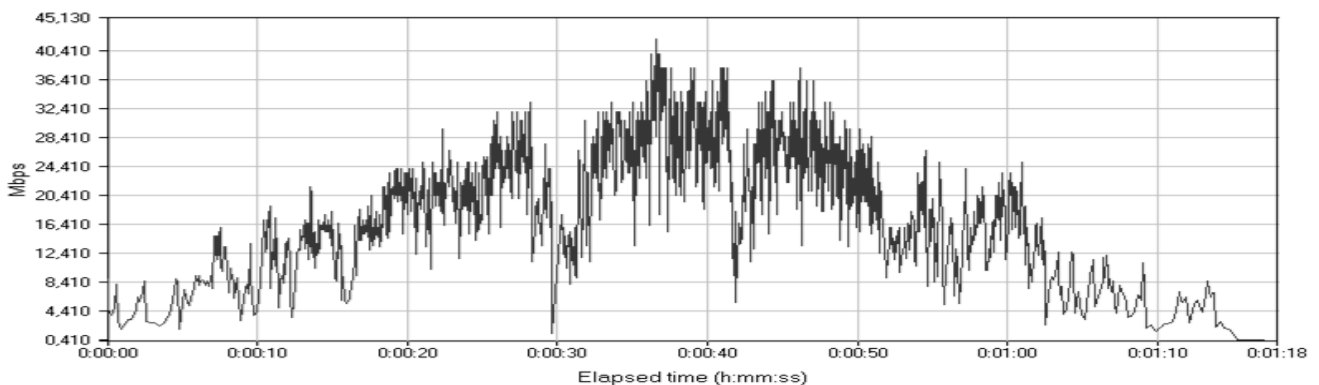


Fig. 7 a. Throughput vs. time by velocity 20 kmph.

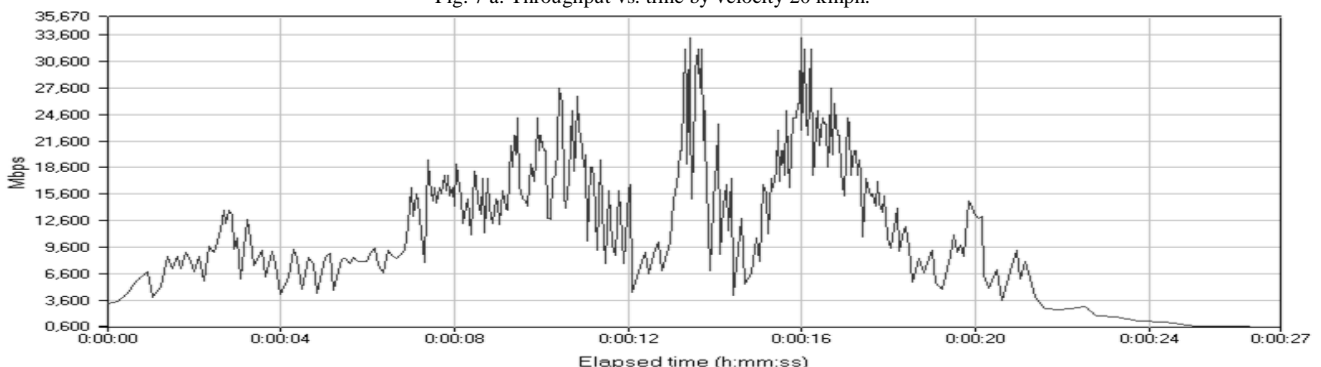


Fig. 7 b. Throughput vs. time by velocity 100 kmph.

TABLE 5  
MEASUREMENTS RESULTS FOR GOODPUT DETERMINATION

Vehicle speed (kmph)	Useful connectivity window(s)	Transferred file rate
20	77,717	1440
40	53,758	903
60	41,682	571
80	32,823	437
100	26,347	324

Figure 9 illustrates the average throughput and useful connectivity windows at different speed of car. As the speed increases, the connectivity windows for which the client is in range of access point decreases near to double, from 77 seconds at 20 kmph to 41 second at 60 kmph. However, even at 100 kmph there is still a 27 seconds window for data transmission, which stands for a usable connection opportunity for moving client.

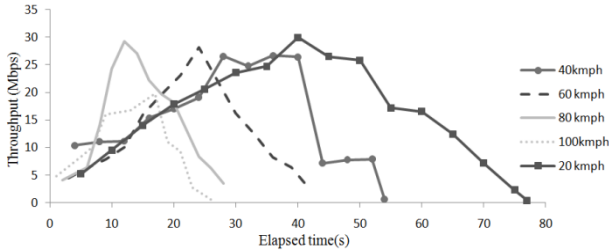


Fig.9. Throughput from a mobile sender at different speeds

The throughput versus velocity of the car is variable and clearly shows at every velocity the phases of oncoming to and moving away from access point. In the both phases derive low throughput rates. The transition to the peak throughput phase occurs relatively quickly. At lower velocity the transition form is gently sloping. This affirm the case where the access point transmission bit rate received by the testing vehicle changes as the vehicle passes through the access point's coverage range.

Goodput is defined [20] as the application throughput, i.e. the number of bits per unit of time excluding protocol overhead and retransmission packet. It is calculated by multiplying size of sending file by transferred file rate and dividing by useful connectivity window.

In fact, goodput rate is dependent on the vehicle speed and decreasing proportionally with the vehicle speed.

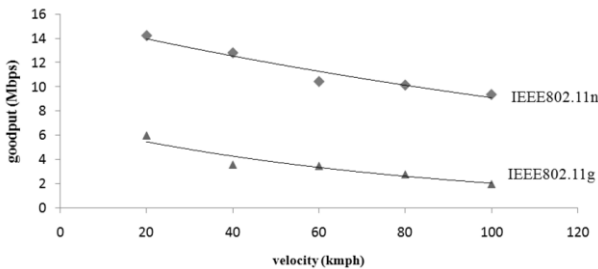


Fig.10. Comparison of basic performances goodput vs. velocity over IEEE802.11 g and n.

Figure 10 shows that the goodput of the IEEE802.11n standard in comparison with IEEE802.11g. Improved standard presents a 2 ½ time preferably performance of goodput in mobile environment then legacy.

Calculating the results from field trial with IEEE802.11n standard devices was obtained that the average goodput vs. velocity relations and in the same way derived IEEE802.11g the data from [18], results can be approximated as follow:

$$goodput_{11n}(v) = 15.517 \cdot e^{-0.005 \cdot v} \quad (5)$$

$$goodput_{11g}(v) = 6.9881 \cdot e^{-0.012 \cdot v} \quad (6)$$

## V. ANALYTICAL MODEL

Realizing field trials for goodput evaluation of vehicular wireless communication systems is very difficult and costly. Numerous vehicles and communication equipments need to be involved, and also many experimenters need to be employed. In this case, it is highly desirable to obtain theoretical analysis with real data from small scale scenarios of practical measurement results and perform an evaluations prior conducting field trials. In term of analyses methodic, were mapped previous approximations of vehicle mobility (4) and goodput (5-6) into simple Markov M/M/1//N chain model. Use of Markov model is novel for evaluation of IEEE802.11n standard in mobile environment comparing with legacy standard (i.e. IEEE802.11g).

### A. System model description

For this model computation, was consider the case where the access point's transmission data rate is variable through the access point coverage range, each vehicle maintains its speed (average velocity of all the vehicles), and an access point sending file data to all vehicles within coverage range.

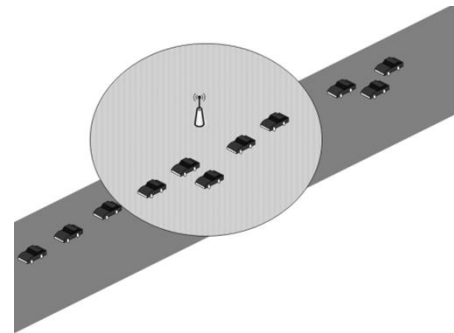


Fig.11. Analytical model scenario.

Primitive packets flow from finite wireless mobile users N and arrive to infinite buffer of the system and are served by the server or wireless router shown in Fig. 12.

In this case our system is expressed by Kendall notation like M/M/1//N[21], where first M – defines exponential

inter arrival times between packets distribution (Poisson process), second M – defines exponential data packets transmission time distribution, next number defines transmission channel and N – represents number of packet sources. Processes in M/M/1//N system are birth-death process and Markov state transition diagram is shown in Fig. 13.

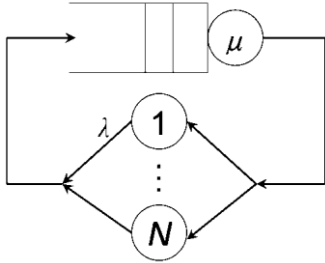


Fig. 12. M/M/1//N system structure

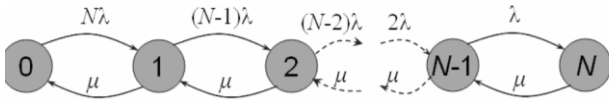


Fig. 13. Markov state transition diagram of M/M/1//N birth-death system

Queuing models for M/M/1//N systems are very elegant in analysis of wireless data networks at transmission channel with no packet loss and vehicles simultaneously under the coverage of the access point  $v$ . speed –  $N(v)$  (i.e.  $\rho(v)$  from (4)). Based on this M/M/1//N queuing model the average goodput by a vehicle can be computed as follows:

$$goodput(v)_N = goodput(v) \cdot (1 - \pi_0) / N(v), \quad (8)$$

where  $\pi_0$  represent probability of idle system

$$\pi_0 = \left[ \sum_{j=0}^{N(v)} \frac{N(v)!}{(N(v) - j)!} \cdot \frac{\lambda^j}{\mu^j} \right]^{-1}, \quad (9)$$

where  $j=1,2,3,\dots,N(v)$ ,  $\mu$  – the data packet transmission rate of channel between vehicular and base station,  $\lambda$  is packet arrival rate in the coverage range of the access point.

### B. Results

In the computation to the analytical model in previous subsection, was constructed a topology with an access point sending file data to all vehicles within coverage range of access point. In the computation, each vehicle maintains its speed as it drives through the access point coverage range as shown in Fig.11. The computations compare the results derived from trial field tests with analytical model for the single-lane in vehicle traffic.

The range of values was investigated for goodput that a vehicle can obtain from access point.

From the Figure 14 can make the following observation:

- At low traffic density corresponding to high vehicle speed, there are few vehicles and as such there is a few connections using the access point resource and the value of goodput is close to maximum. It is about two times less than plausible maximum goodput.
- At low velocity increase value of vehicles and bandwidth connections increases leading to lower values of goodput for a vehicle.

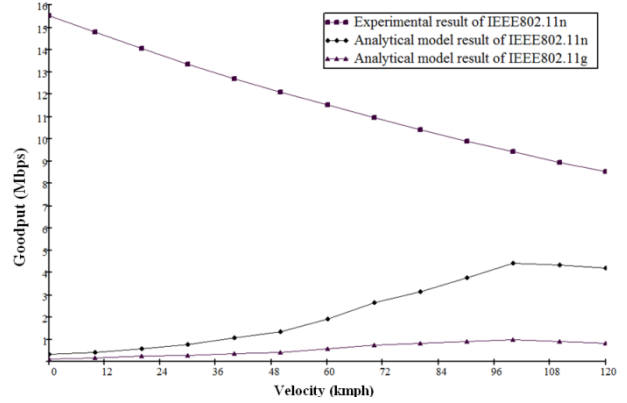


Fig. 14. Average goodput of a vehicle at different speed in traffic scenario.

- Despite reduction of maximum goodput due to mobility at velocity from 50 kmph to 100 kmph improves the goodput value of a vehicle. The same result shows a legacy technology.

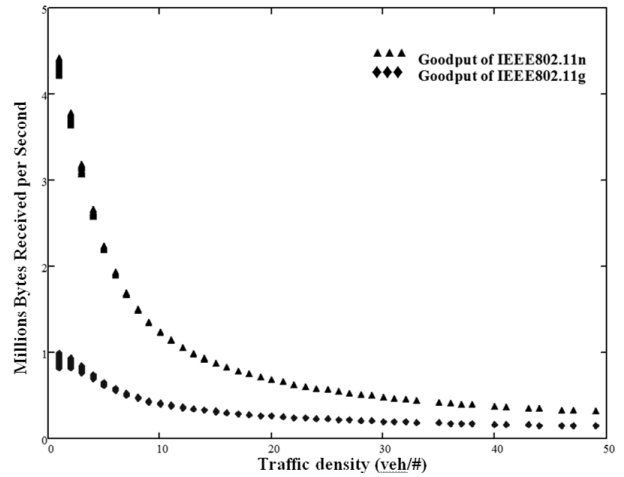


Fig. 15. Average value of bytes received for single-lane of vehicle traffic during the connectivity windows expressed in distance unites (#) ~300 m.

Figure 15 shows comparison results derived from analytical model of two standards. The average number of bytes received by a vehicle in M/M/1//N model at the low traffic density is about four times higher compared to the result of IEEE802.11n standard either legacy standard. By the high traffic density the goodput that a vehicle can be achieved by both standards is less than 500 Kbps. This is due to a higher number of contending vehicles for access point's resources and increasing the access point's

coverage range may not be the way to improve a mobile user the amount of data which can be down- or up- loaded within useful connectivity window. The traffic conditions and useful connectivity windows play significant role of a vehicle's average goodput that can be perform in V2I scenario with one access point.

## VII. CONCLUSION AND FUTURE WORK

In this article was presented field trial evaluations together with theoretical analyses of the IEEE802.11n standard comparing with legacy standard in the vehicle environment. The numbers of test were performed in the context of simple scenario of one vehicle and access point. At various velocities has been tested the goodput of WLAN. Wireless network under fluent number of vehicles respectively active users simultaneously realizing such field trials for goodput evaluation is very difficult and costly. Therefore a simple mathematical model for goodput evaluation of vehicular communication systems in V2I scenario was presented and analyzed for understanding the basic processes in wireless data networks prior to conducting larger field trials. And it is also important to note that results were showed her serve as information for future analyzes and vehicle wireless network systems designers to be aware of the system's possible limitations.

## ACKNOWLEDGMENT

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**Janis Jansons** received his B.S. degree in telecommunications (2003), Institute of Telecommunication, and M.S. degree, in computerized control, information and electronic systems of transport (2007), Chair of Transport Electronics and Telematics, from Faculty of Electronics and Telecommunications (FET) in Riga Technical University. Now he is pursuing his Ph.D. degree in computerized control, information and electronic systems of transport. His research interests focus on wireless short range communications for intelligent transport system. Contact him at Riga Technical University, Faculty of Electronics and Telecommunications, Chair of Transport Electronics and Telematics, Riga, Latvia, e-mail: janis.jansons\_1@rtu.lv.

*Tēzes – Šajā rakstā tiek atspoguļots bezvadu bāzes stacijas caurlaidības novērtēšanas modelis. Šeit tiek izmantots bezvadu piekļuves punkta modelis kā rindošanas sistēma ar dažāda veida pieprasījumiem un ciklisku automobiļu kustības modeli. Bezvadu mobils tīkls satur dažādus parametrus, kā klientu attālumus līdz piekļuves punktam, klientu daudzums bezvadu tīkla darbības zonā, klienta pārvietošanās ātrums un kustības tips. Šie parametri tika analizēti un atspoguļoti šajā rakstā.*

*Тезисы - В этой статье представлена модель оценки пропускной способности беспроводной базовой станции. Использовалась модель беспроводного пункта доступа как система массового обслуживания с различными видами запросов и модели циклического движения автомобилей. Беспроводные мобильные сети имеют различные параметры такие как расстояния между клиентами и узлом доступа, число клиентов в беспроводной зоне действия сети, скорости движения клиентов и тип курсирования транспорта. Эти параметры были проанализированы и представлены в этой статье.*