International Journal of Digital Information and Wireless Communications (IJDIWC) 2(1): 46-50
The Society of Digital Information and Wireless Communications, 2012(ISSN 2225-658X)

Vehicle-to-Infrastructure Communication based on IEEE 802.11g

Janis Jansons, Nikolajs Bogdanovs, Aleksandrs Ipatovs
Department of Transport Electronics and Telematics
Riga Technical University
Riga, Latvia
janis.jansons_1@rtu.lv

Abstract – **Vehicle-to-infrastructure (V2I) communication based on wireless local area network (WLAN) IEEE 802.11 standard technology can support user in-motion to achieve preferable Internet connectivity. Wireless access for the vehicular environment (i.e. IEEE802.11p) provides the required standardization for vehicle-to-vehicle V2X communication solutions supporting raw data rate up to 27 Mbps. This standard is created for urgent short message transmission. Otherwise, for transmission of large amount of data alternative solutions may be proposed. In this paper we present an experimental study of IEEE802.11g using off-the-shelf devices in vehicle-to-infrastructure small scale scenario. In order to evaluate the V2I the type of communication in large scale scenario, in this paper we propose analytic model to characterize the goodput of WLAN-based networks using Markov process.**

Keywords - Short Range Vehicle Network; 802.11g; wireless network; goodput; network performance; transport; mobile stations; auto traffic; vehicle speed

I. INTRODUCTION

The demand for reduction of vehicular accidents, traffic congestions, transportation time, fuel consumption and environmental impact of road transport are essential area of research. Researchers are greatly interested to develop vehicular communication systems - 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 backbone of cooperative Intelligent Transport Systems (ITS). In Europe, USA, Japan and other countries are great efforts made from auto-industries 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 Vehicle Short Range Communications. 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.

Wireless networking based on IEEE802.11 technology 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 IEEE 802.11g standard promises to improve and extend most popular WLAN standards by significant increasing throughput 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 involved, 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 performance 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 the performance of WLAN depending on number of active users. Then, in Section 3 provides the performance of WLAN depending on distance to access point and performance evolution of practical results. After then, in Section 4 WLAN goodput variations depending on vehicle speed and Doppler spread. In Section 5 we describe a queuing model of V2I communication with one wireless access point and variable amount of active mobile clients (vehicles). After demonstrating the analysis results in this Section. Section 6 summarize and concludes this paper.

II. GOODPUT VARIATION DEPENDING ON NUMBER OF ACTIVE USERS

In our research we use goodput as the application level throughput, i.e. the number of useful information bits, sent from source of information through the network to a certain destination, per unit of time. This useful information is a amount of data which exclude protocol overhead bits as well as retransmitted data packets. If a file is transferred, the goodput that the user experiences correspond to the file size in bits divided by the file transfer time. The goodput is lower than the throughput, which generally is lower than network access connection speed (the channel capacity or bandwidth).

To evaluate goodput of WLAN in stationary mode depends on a number of active users we made several experiments. For the experiment we used off-the-shelf wireless equipment such as Linksys WRT54GL access point (AP) with Tomato v2.28 firmware and five regular laptops with WLAN adapters.

In our measurements to analyze the goodput of WLAN, we used IxChariot program (version 5.4). IxChariot server was connected to the access point through 100 Mbps LAN. Client version of IxChariot program we set up on active users' laptop in our network. An important feature of network structure, shown in Fig. 1, is the AP sharing of its bandwidth among the active users that are simultaneously under the coverage of the AP.

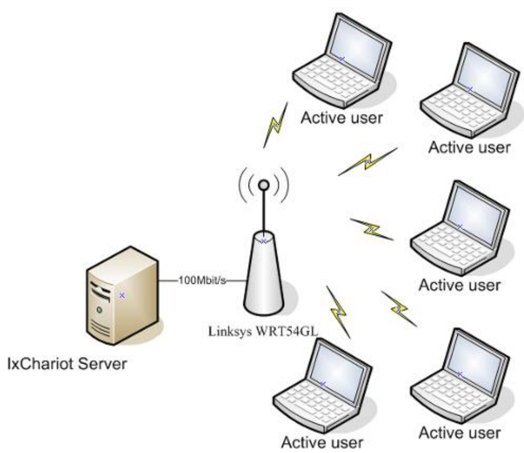

Figure 1. Visual structure of network

For establishing quick wireless connectivity, the AP and the user's device WLAN adapter were configured to use the same frequency channel and service set identification (SSID), the encryption has been deactivated. IP addresses for all connections have been entered prior to avoid internet protocol (IP) address acquiring process using dynamic host configuration protocol (DHCP). The system response time was taken to calculate and evaluate the network goodput performance using TCP protocol. The main measurement setup parameters for the AP and an active users' device are summarized in Table 1.

TABLE 1: EXPERIMENTAL SETUP

Item	Setting
Wireless technology	802.11g
Channel	fixed
Channel wide	20MHz
Frequency band	2.4GHz
Cable connection	up to 100 Mbps
Maximal data rate	up to 54 Mbps
Size of sending file	100000 Bytes
Transport protocol	TCP
IP addresses	Fixed

From our experimental results we derived the maximal goodput (18Mbps) of the network with one active user. The number of active users we increased one by one. We note that the average goodput values are depending on number of active users. Fig. 2 depicts the average wireless network goodput with one and three active users. The goodput is plotted versus elapsed time of measurements.

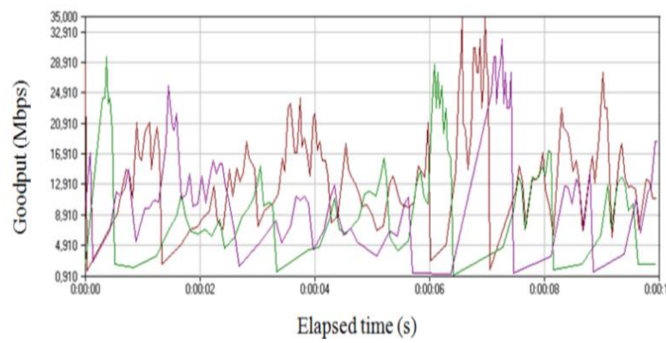

Figure 2. Goodput analysis in the "Chariot" program

Fig. 3 shows that the goodput of wireless network decrease in dependence from number of active users (workstations) and this reduction is not linear. Fig.2 shows that average goodput main decrease exponentially.

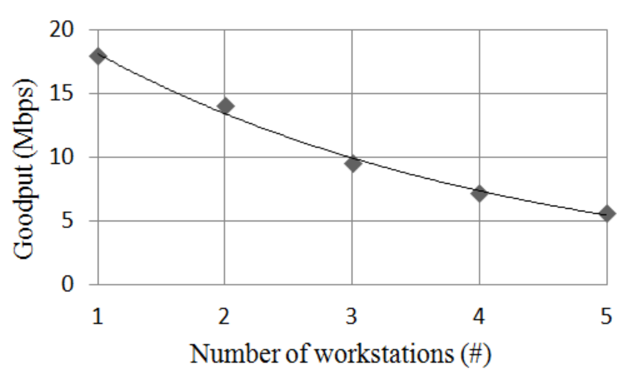

Figure 3. Experimental goodput (Mbps) decrease in dependence from number of workstations and exponential trend line.

It is possible approximately finding real goodput for each stationary wireless network depending on number of workstations with this graph.

III. Goodput Variation Depending on Distance to Access Point

It is clear that wireless network goodput depends on distance to the access point. 802.11g standard uses OFDM and Complementary Code Keying (CCK) to support higher raw data rate "over the air" (up to 54 Mbps) and rate in MAC Layer (up to 25 Mbps). OFDM is a multi-carrier modulation which converts single high-rate bit stream to low-rate 64 parallel bit stream. Each sub-carrier can be modulated by binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), 16-symbol quadrature amplitude modulation (16QAM), 64-symbol quadrature amplitude modulation (64QAM). Wireless network goodput depends on which modulation is used.

In Fig. 4 depicted the blue line which shows experimental goodput evaluation depending on distance to the router in outdoor environment. The result of the performance test show that the average goodput are decreasing while the distance is increasing due to the well known power loss model. At near distance (1 m) the average goodput is about 17 Mbps. At 25 m, the figure shows slow decreased values and can be explained due to same modulation with signal reflection errors. In additional tests we have observed that the maximum goodput is about 3 Mbps at the distance of 200m from the AP. We conclude that our tested IEEE 802.11g devices can communicate over large distances in outdoor environments with high goodput performance.

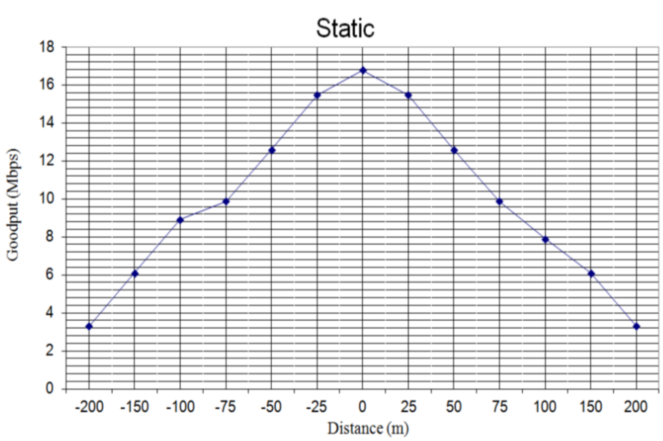

Figure 4. Goodput (Mbps) in wireless network depending on distance (m) to the access point

To identify the maximum goodput depending on distance and number of active users we merged the previous experimental results. In Fig. 5a/b we can observe the goodput change.

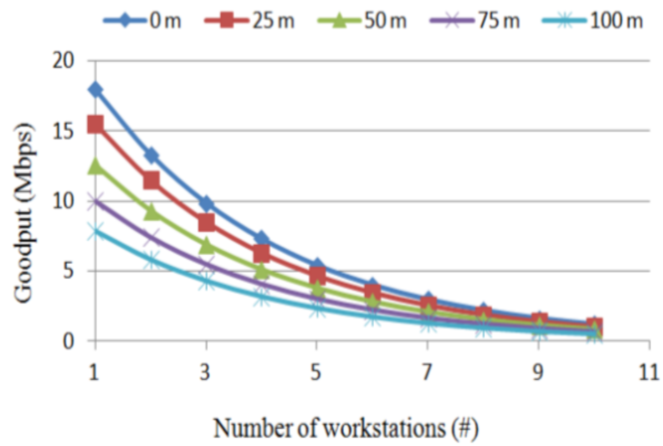

Figure 5a. Goodput (Mbps) dependence from number of workstations and distance (m) to the access point

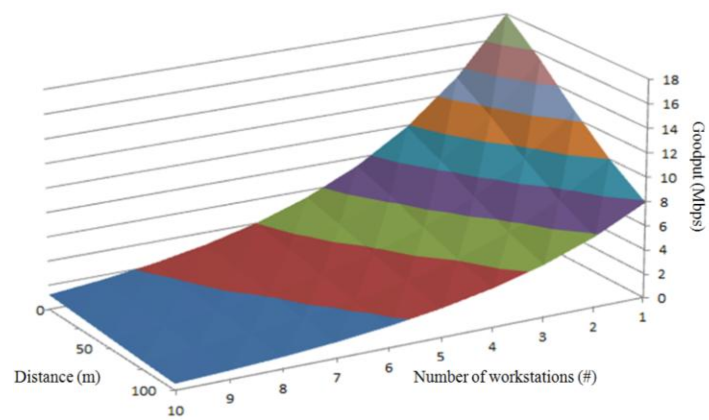

Figure 5b. 3-dimension graph of goodput (Mbps) dependence from number of workstations and distance (m) to the access point

There are three different goodput meanings. The first can be called overall, the second - conditional goodput and the third – individual goodput. In Fig 5a conditional goodput on 100 m distance from the access point for two users is 6 Mbps, but average individual goodput is only 3Mbps. Conditional goodput mean AP goodput when it serves a certain number of active users. Conditional goodput is less than overall, because AP is involved in the control process with some user stations. Overall goodput can be found when only one client connects to the AP and there are no overheads in the wireless network.

IV. Goodput Variation Depending on Vehicle Speed and Doppler Spread

Short range vehicle network goodput depends on mobile station speed. It can be found experimentally using mobile station and IxChariot program. Experiments should be made at vehicle different speeds. Of course there should be more than one access point, because the vehicle will be in one access point zone for a short time on high speed. Wireless

Distribution System (WDS) can connect some routers in one network without wires. There were used three routers in the experiment [3]. In Fig.6 shows the goodput dependence from different speeds of the vehicle. As WDS was used significant loss can be seen in left and right zones of the graph. Red point on the graph shows static results in different points of the route.

This graph shows that this wireless network for mobile users can provide the necessary throughput for mobile stations on speed till 75 km/h. When the speed is higher, mobile station drops the connection on the second router and reconnects only on third router.

Doppler shift may cause goodput decrease if the transmission technique is sensitive to carrier frequency offsets or if the relative speed is too high.

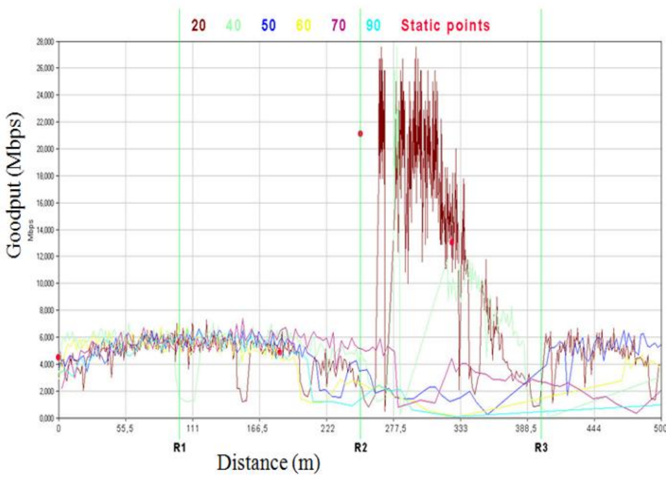

Figure 6. Goodput (Mbps) analysis on different speeds (km/h) in short range vehicle network

In [4] was theoretically and experimentally proved that IEEE 802.11g equipment with OFDM technology is insensitive against frequency shifting that cause power leakage between OFDM subcarriers on different vehicle speeds. But on the speed 75 km/h the signal can be dropped at all.

This method is good only for one mobile object. But in real life it is difficult to find how many mobile objects are in the access point working zone and wireless network goodput can't be evaluated. How to find it?

V. Network performance with finite number of vehicles in range of base station

In this section we have analyzed the goodput of wireless network depending on vehicle traffic behavior in relation to the amount of in – motion active sources. We present a traditional wide performance measure analysis of wireless networking system with a finite number of active mobile sources.

Firstly, we have analyzed the practical measurement results from different papers. The authors [6,7,8] use scenarios that generally seem similar to each other, but each test shows different results due to authors' individual approaches. Common results show that the maximum average goodput is with minimal car speed and near the access point. We focus our analysis of vehicle – to – infrastructure communication and Gass et al. [9]. This approach seems to us appropriate. The author uses a scenario that is similar to Ott and Kutscher's [10] one, where UDP and TCP use to transfer data between a car and static located access point. This data from Gass et al. paper we have approximated to average goodput at the car speeds and get the following equation:

$$goodput(v) = -0.19768 \cdot \ln(v) + 1.1886 \qquad (1)$$

, where v – average car speed.

Secondly, in order to understand the traffic phenomena we studied the behavior of the cars movement where a flow of cars traveling on a single – line road can vary from one to finite. Some authors in [11]-[13] provide analysis of vehicular mobility. Approximate Intelligent Driver Model simulation date we consider the cars mean value N(v) at the speed v can be defined as follow:

$$N(v) = 103.05 \cdot \exp(-0.0349v) \qquad (2)$$

Gass et. al. investigation packet loss and usable data transfer window at various speed v show that data can be successfully transmitted with negligible losses at a range of 150 m from AP. Consider a 300 m window for data transmission is even at 120 km/h, which represents a usable information exchange - goodput opportunity for in motion active source.

Further examination of wireless network goodput in relation to amount of mobile users mapped on previous approximations into Markov birth-death system can be mathematically evaluated. Queuing models for M/M/1//N systems are very elegant in analysis of wireless data networks in transmission channel with no packet loss and finite customer population – *N(v)*. Using this desired consideration according to the Markov queuing system we can easily write the following equation the throughput of a wireless network $\eta(v)$ at speed of cars v,

$$\eta(v) = goodput(v) \cdot (1 - \pi_0), \qquad (3)$$

where π_0 represent the probability of free system or our case one in-motion active customer in wireless network range:

$$\pi_0 = \left[\sum_{j=0}^{N(v)} \frac{N(v)!}{(N(v)-j)!} \cdot \rho^j \right]^{-1}, \text{ j=1,2,3....N(v)} \qquad (4)$$

where ρ is utilization of the wireless transmission channel value [0.1,0.97]. Fig. 7 shows goodput of wireless network calculated using analytical model:

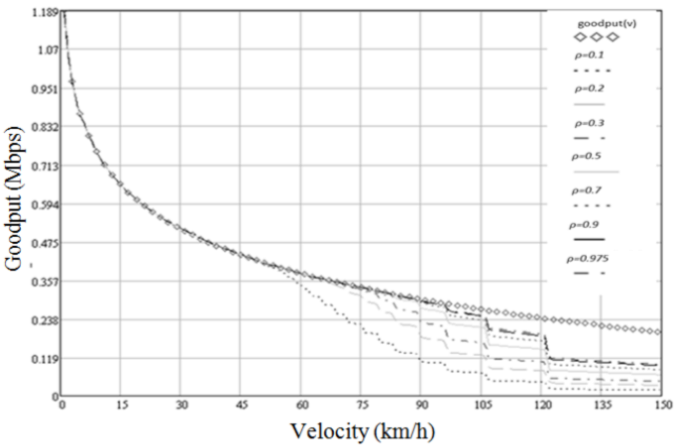

Figure 7. Average individual goodput over speed of in-motion active user by vary utilization of the wireless transmission channel

The results above show that the wireless networks based on 802.11 standards can also support finite mobile users to transmit and receive data. At speed 10 km/h to 50 km/h and variable utilization (from 10% to 97.5%) the data transferred reduces according Gass et al. experimentally measured data. We observed that at the speed 75 km/h and utilization $\rho=0.1$ the goodput of wireless network is dropped over two times down and continue to diminish in all value of network utilization degrees. Our mathematical analysis results show that the poor performance of the vehicular networks could be affected by vehicle traffic behavior.

CONCLUSION

In this paper have been analyzed the data communication performance of user in vehicles to obtain Internet connectivity. In particular, the measurements indicate that the goodput in the short range vehicle network is dependent of many factors: (1) number of active users; (2) the distance between vehicle and roadside wireless access point; (3) velocity of active user. Realizing of large scale field tests for evaluation of short range vehicular network is very difficult and costly, because many vehicle and communication equipment need to be rented or procured. Give such problem is important to derive a practical analytical model, which will give a possibility to understand the basic performance of such network prior to conduct large scale vehicle communication scenario. This model is able to quantify the impact auto traffic parameters on the goodput of short range vehicular network.

REFERENCES

[1] IEEE Standard, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments," IEEE, 2010.

[2] A.Ipatovs, E. Petersons, “Performance Evaluation of WLAN depending on number of Workstations and Protocols”, Proceedings of International Conference Electrical and Control Technologies, ISSN 9955-25054-2, 2006, pp. 266-270.

[3] A.Ipatovs, E. Petersons, “An Experimental Performance Evaluation of the Wireless Network for Mobile Users”, Electronics and electronical engineering, ISSN 1392-1215, 2009, No. 5(93), pp. 21-24.

[4] J.Jansons, A. Ipatovs, E. Petersons “Estimation of Doppler Shift for IEEE 802.11g Standard “, Baltic Conference Advanced Topics in Telecommunication, University of Rostock, pp. 73-82, 2009.

[5] L.Kleinrock, R. Gail. “Queueing Systems: Problems and Solutions” John Wiley & Sons; ISBN: 0471555681, 1996, pp. 227.

[6] V. Bychkovsky, et. al., “A Measurement Study of Vehicular Internet Access Using In Situ Wi-Fi Networks,” In ACM MobiCom, 2006.

[7] M. Wellens, B. Westphal, and P. Mähönen, "Performance Evaluation of IEEE 802.11-based WLANs in Vehicular Scenarios", in Proc. VTC Spring, 2007, pp.1167-1171

[8] D. Hadaller, et. al., “Vehicular Opportunistic Communication Under the Microscope,” In ACM MobiSys, 2007.

[9] R. Gass, J. Scott, C. Diot, “Measurements of In-Motion 802.11 Networking”, in Proc. of WMCSA'06.

[10] J.Ott, D. Kutscher, “Drive-thru Internet: IEEE 802.11b for Automobile Users,” IEEE Infocom 2004 Conference; 2004.

[11] A. Kesting, “Microscopic Modeling of Human and Automated Driving: Towards Traffi c-Adaptive Cruise Control”, Ph.D. Thesis, Technical University of Dresden, 2008.

[12] S. Krauss, “Microscopic Modeling of Traffic Flow: Investigation of Collision Free Vehicle Dynamics,” Ph.D. Thesis, University of Cologne, Cologne, Germany. 1997.

[13] M. Fiore, et. al., “Understanding Vehicular Mobility for Network Simulation”, in Proc. of the 1st IEEE Workshop on Mobile Vehicular Networks (MoVeNet’07), part of MASS’07, Pisa, Italy, October 2007.

[14] M. Treiber, A. Hennecke, and D. Helbing, “Congested traffic states in empirical observations and microscopic simulations,” Physical Review E, 62, pp. 1805–1824, 2000.