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Model for Wireless Base Station Goodput Evaluation in Vehicular Communication Systems

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Introduction

Vehicular communication systems have increased in popularity and importance in recent years. In the 1970s researchers were fascinated by the idea of radio-equipped vehicles that mutually exchange traffic information to improve driving conditions. The Comprehensive Automobile Traffic Control System (CACS) project in Japan was initiated in 1973, and probably it was the first research project worldwide on this topic [1]. Vehicular communication systems are interesting in both academia and industry, driven by reduction of road traffic congestion, reduction of CO_2 emission, prevention of traffic accidents and enhancement of the public and social role of vehicles. Much research remains to be done to bring to the vision of future intelligent vehicular communications applications. Vehicular networks form a novel class of wireless networks are spontaneously formed between moving vehicles equipped with wireless interfaces of similar or different technologies.

Vehicular networks, also known as VANETs (vehicular ad hoc networks), are examples of real applications of ad hoc networks enabling vehicle-to-vehicle and vehicle-to-infrastructure communications. These networks have significantly different characteristics compared to other wireless and mobile networks especially concerning high speed and unpredictable topology.

Previously [2–5] have been analyzed the wireless network under different conditions. Traditional wide performance measures analysis of wireless networking system with finite number of active mobile sources and constant service rate have been used. And base model for performance evaluation is M/M/1//N queue system model.

But in this paper, we evaluate the throughput of wireless network under variable number of vehicles, which vary according to vehicles traffic model. Moreover packet service rate in base station also is taken in attention.

Field trials for goodput evaluation of vehicular wireless communication systems is very difficult and costly because many vehicles and communication equipment need to be purchased or rented, and also many experimenters need to be employed. Given such problems, it is highly desirable to use mathematical analyzes and performance evaluations prior conducting field trials as it is made in this work.

Goodput variation depending on vehicle speed and distance to wireless base station

First of all there were analyzed practical measurement results from different papers. The authors [7, 8, 9] use scenarios that generally seem similar to each other, but each field trial test shows different results due to authors individual approaches. Common results show that the maximum average goodput is when car speed is minimal and vehicle is near to the access point. We focus our analysis on vehicle – to – infrastructure communication.

For vehicular traffic evaluation Gass et al. [10] and Rubinstein et al [11] approach seems for us appropriate. The authors use a scenario that is similar to Ott and Kutscher's [12] one, where UDP and TCP use to transfer data between a car and static located access point. This data from Gass et al. and Rubinstein et al. paper authors have approximated to average "goodput"(the number of bits per unit of time excluding protocol overhead and retransmission packets) on different car speeds.

As a result of this the following equations are proposed:

Gass et al.

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

Rubinstein et al.

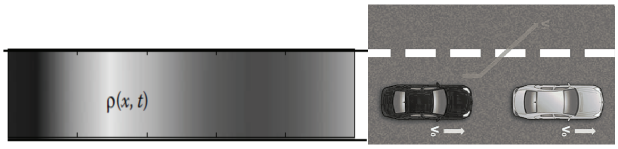
$$goodput(v) = -0.02 \cdot v + 3.5333\ , \qquad (2)$$

where v – average car speed. The practical measured results from above mention author's papers are different. From Gass et al. measurement results authors use average amount of data transferred over TCP bulk traffic using IEEE 802.11b standard, but from Rubinstein results- UDP traffic in IEEE 802.11g. environments.

Gass et. al. show that data can be successfully transmitted with negligible losses at range of 150 m from base station (AP). Range of 300 m window for data transmission is real, even vehicle speed is 120 km/h, which represents a usable information exchange – "goodput" opportunity for in motion active source.

Modeling of mobility

In order to understand the traffic phenomena a simple model of traffic was taken, where cars follows one by one and quantity of cars can be changed from one till N.



a) b)

Fig. 1. Illustration of macroscopic (a) and microscopic (b) traffic modeling approaches

Traffic engineers distinguish four classes of mobility models: macroscopic, mesoscopic, microscopic and submicroscopic. A number of papers [13–16] provide analysis of vehicular mobility. In those papers, are discussed different vehicular mobility models in terms of their analytical description and verified their realism. Based on those studies, car-following models are the best approach for studies of vehicular networks. Car-following models describe the behavior of each driver in relation to the vehicle ahead. Authors use a car-following model from Treiber et al. [16], called Intelligent Driver Model (IDM). Approximating IDM simulation date we resulted that the cars mean value N(v) at the speed *v* can be defined as follow

$$N(v) = 103.05 \cdot \exp(-0.0349v)\,. \qquad (3)$$

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 [17]. Finally one can use (3) relationship for M/M/1/N model analysis.

Analyses of wireless communication performance with finite customer quantity

Further examination of the throughput of wireless network in relation to amount of mobile user we mapped previous approximations into Markov M/M/1/N model.

Primitive packets flows from finite wireless mobile users N and arrives to infinite buffer of the system and are served by the server or wireless router shown in Fig. 2.

In this case our system is expressed by Kendall notation like M/M/1//N, 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. 3.

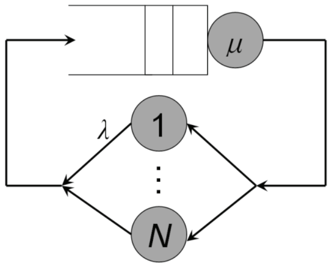


Fig. 2. M/M/1//N system structure

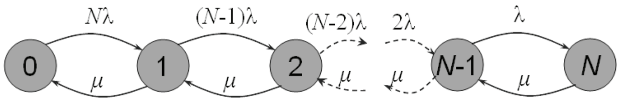


Fig. 3. Markov state transition diagram of M/M/1//N birth-death system

Queuing models for M/M/1//N systems are very elegant in analysis of wireless data networks at transmission channel with no packet los and finite customer population – *N(v)*. Using this desired consideration according to Markov queuing system we can easily write the following equation the throughput of wireless network *η(v)* at speed of cars *v*

$$\eta(v) = goodput(v) \cdot (1 - \pi_0)\,, \qquad (4)$$

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

$$\pi_0 = \left[\sum_{j=0}^{N(v)} \frac{N(v)!}{(N(v)-j)!} \cdot \rho^j \right]^{-1}, \qquad (5)$$

where $j=1,2,3....N(v)$, $\rho=\lambda/\mu$ – utilization of the wireless transmission channel value [0.1, 0.97], $\rho = \frac{\lambda}{\mu}$, μ – the data packet transmission rate of channel between vehicular and base station, λ – is data packets arrival rate.

Fig. 4 shows wireless network performance measures calculated using analytical model.

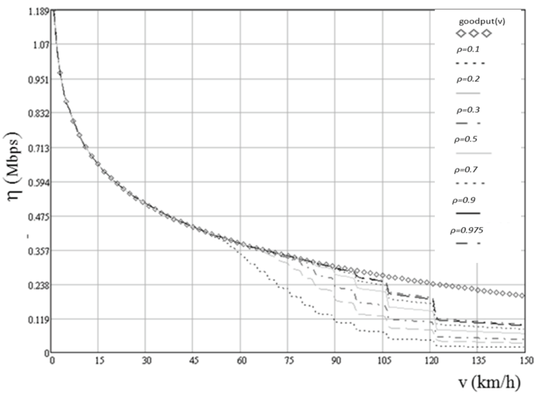


Fig. 4. Average throughput over speed of in-motion active user by varies utilization of the wireless transmission channel with Gass et al. data

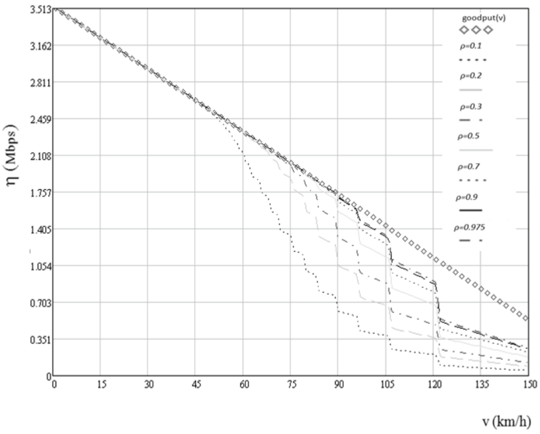


Fig. 5. Average throughput over speed of in-motion active user by vary utilization of the wireless transmission channel with Rubinstein et al. data

The results above shows 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. and Rubinstein et al. experimental measured data. We observed that at the speed 75 km/h and utilization $\rho=0.1$ the throughput 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 in relation to amount of in-motion active user.

Conclusions

In this article was evaluated the throughput of wireless network under fluent number of vehicles, which vary based on mobility model.

This model for wireless base station goodput evaluation in vehicular communication systems is useful and cost-effective for analysis processes in wireless data networks prior to conducting field trials. The Markov chains give possibility for easy and quick analysis of the systems under fluent number of in-motion customers.

Wireless mobile networks have different goodput that is variable depending on the speed of mobile users. Based on this average goodput seriously come down when vehicles speed is 75 km/h and more. This recommendation can be used in future modeling of vehicular communication networks.

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In this paper we present the model of wireless base station goodput evaluation. There was used access point model as queuing system with different kind of requests and cycling 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. Ill. 5, bibl. 17 (in English; abstracts in English and Lithuanian).

A. Ipatovs, E. Petersons, J. Jansons. Bevielio ryšio bazinės stotelės taikymas transporto priemonių ryšio sistemose // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 5(111). – P. 19–22.

Analizuojamas bevielio ryšio bazinės stotelės taikymas transporto priemonių ryšio sistemose. Bandymui atlikti buvo naudojama bazinė stotelė, kaip skleidžiamo signalo šaltinis. Buvo analizuojami tokie parametrai, kaip antai: atstumas nuo kliento iki bazinės stotelės, klientų skaičius bevieliame tinkle, automobilio greitis ir eismo tipas. Il. 5, bibl. 17 (anglų kalba; santraukos anglų ir lietuvių k.).