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РОССИЙСКОЙ АКАДЕМИИ НАУК

Научно-производственное объединение
«Информационные и сетевые технологии»

Институт информационных и телекоммуникационных технологий
БОЛГАРСКОЙ АКАДЕМИИ НАУК

РАСПРЕДЕЛЕННЫЕ КОМПЬЮТЕРНЫЕ И ТЕЛЕКОММУНИКАЦИОННЫЕ СЕТИ: УПРАВЛЕНИЕ, ВЫЧИСЛЕНИЕ, СВЯЗЬ (DCCN-2015)

МАТЕРИАЛЫ ВОСЕМНАДЦАТОЙ МЕЖДУНАРОДНОЙ НАУЧНОЙ КОНФЕРЕНЦИИ

(19–22 октября 2015 г., Москва, Россия)

Под общей редакцией д.т.н. В.М. Вишневского

Москва
ИПУ РАН
2015

V.A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences

Research and development company **“Information and networking technologies”**

Institute of Information and Communication Technologies
Bulgarian Academy of Sciences

DISTRIBUTED COMPUTER AND COMMUNICATION NETWORKS: CONTROL, COMPUTATION, COMMUNICATIONS (DCCN-2015)

PROCEEDINGS OF THE EIGHTEENTH INTERNATIONAL SCIENTIFIC CONFERENCE

(19–22 october 2015 г., Moscow, Russia)

Under the general edition of Dr. of Computer Science V.M. Vishnevskiy

Moscow
ICS RAS
2015

УДК 004.7:004.4].001:621.391:007
ББК 32.973.202:32.968
Р 24

Распределенные компьютерные и телекоммуникационные сети: управление, вычисление, связь (DCCN-2015) = Distributed computer and communication networks: control, computation, communications (DCCN-2015) : материалы Восемнадцатой междунар. науч. конфер, 19–22 окт. 2015 г., Москва: / Ин-т проблем упр. им. В.А. Трапезникова Рос. акад. наук ; под общ. ред. В.М. Вишневского – М.: ИПУ РАН, 2015. – 656 с.
– ISBN 978-5-91450-170-6.

В научном издании представлены материалы Восемнадцатой международной научной конференции «Распределенные компьютерные и телекоммуникационные сети: управление, вычисление, связь» по следующим направлениям:

- Архитектура компьютерных и телекоммуникационных сетей.
- Управление в компьютерных и телекоммуникационных сетях.
- Оценка производительности беспроводных сетей трансляции мультимедийной информации.
- Аналитическое и имитационное моделирование сетевых протоколов.
- Теория очередей и теория надежности.
- Беспроводные сети IEEE 802.11, IEEE 802.15, IEEE 802.16 и UMTS (LTE).
- Технология RFID и ее применение в интеллектуальных транспортных системах.
- Проектирование протоколов (MAC-уровня) сантиметрового и миллиметрового диапазона радиоволн.
- Интернет, веб-приложения и услуги.
- Интеграция приложений в распределенных информационных системах.

В материалах конференции DCCN-2015, подготовленных к выпуску Козыревым Д.В. обсуждены перспективы развития и сотрудничества в этой сфере.

Сборник материалов конференции предназначен для научных работников и специалистов в области теории и практики построения компьютерных и телекоммуникационных сетей.

Текст воспроизводится в том виде, в котором представлен авторами

Утверждено к печати Программным комитетом конференции

ISBN 978-5-91450-170-6

ONE AND TWO STAGE SHORT RANGE DRIVE-THRU VEHICLE NETWORKS PERFORMANCE EVALUATION

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Abstract

In this paper were presented experimental data and model for evaluating the data transmission speed between the remote moving object-vehicle and base station in wireless networks 802.11n and 4G-LTE standarts. Network of 802.11n standart represent first stage of overall two stage network, involving 4G-LTE channel. The experimental resalts are used for evaluation of actual speed of data transmission between the moving vehicle and base station by using IxChariot program. Network Goodput depending on vehicles speed and vehicles density on road are represented too.

Keywords: 802.11n, 4G-LTE standarts, model, Goodput

1. Introduction

Short-range vehicle-roadside or V2I communication is expected to be part of the future intelligent transportation system (ITS) in order to increase the safety of the roads and efficiency of the traffic. Therefore, investigation on proper communication for ITS are increasing. Today, the IEEE 802.11n and 802.11ac standard for high data rate wireless networks is widespread and costs effective. Extension of this standard could be a part of V2I communication technology.

IEEE 802.11p standard was specially developed for Short Range Drive-thru vehicle Networks, but it use 5.85-5.925 GHz frequencies. These frequencies are paid and the equipment is not cheap. Unlike the specially developed standard 802.11p allows transferring short official reports of urgent character only. Protocols 802.11g/n/ac allow large-scale data transfer at high speeds, and passing to free range of frequencies. The problem is – it is necessary to transfer large-scale data in short time intervals during movement of vehicle. The losses appear during transferring from zone to zone.

Nowadays main wireless system standard is the 802.11n. This standard replaces the 802.11g standard. Significant improvement of quality of signal and goodput also should be observed in utilization of this standard in the Drive-thru Internet system. To prove this fact and to estimate improvements some experiments were conducted, the results and the analysis are described below.

We want once again to refer about usefulness of utilization of the 802.11n standard in Drive-thru Internet system, unless the utilization of specially designed 802.11p standard:

- Equipment for the 802.11n standard is cheap and available.
- Frequencies of the 802.11n standard are free of charge.
- The 802.11p standard does not provide transfer of data large amount and it is developed for transfer of short messages.

All these advantages indicate on feasibility of utilization of the 802.11n standard in the Drive-thru Internet system.

The uniqueness of this research is development of real Drive-thru Internet system for experiments. Experiments for the 802.11n standard were conducted in polygon Rumbula in Riga. Inter-connected roadside access points (APs) ASUS RT-N16 with firmware dd-wrt.v24 were used as workstations. This firmware supports WDS.

In plain terms, this technology allows the access points to establish wireless connection not only with wireless customers, but also between themselves, extending the zone of wireless net action. The main advantage to such net is that its access points are interconnected, comprising a drive-thru Internet system. In this case, there is no need to use landline nets for connection of access points. The net constructed using WDS technology allows the mobile stations to switch from one access point to another without losing connection with wireless net. Figure 1 shows the scheme of the Inter-connected roadside access points (APs) interconnection via WDS.

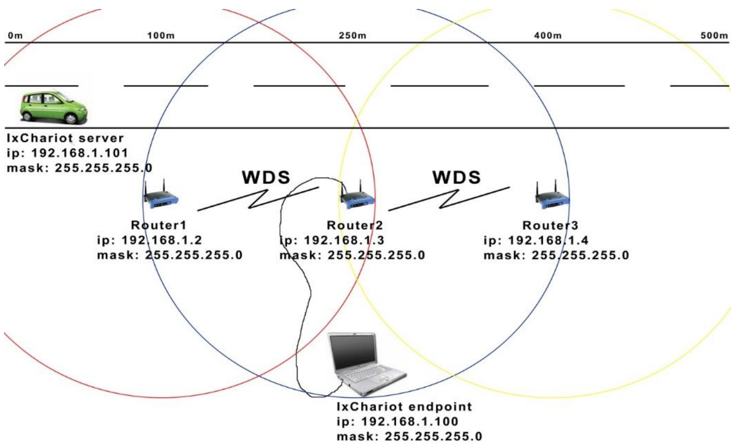

Figure 1: Connection scheme of Inter-connected roadside access points (APs) and zones of their activity.

The graph in Figure 2 shows goodput dependence on different speeds of Drive-thru vehicle (20km/h and 100km/h) with 802.11n standard. As WDS was used significant loss can be seen in left and right zones of the graph.

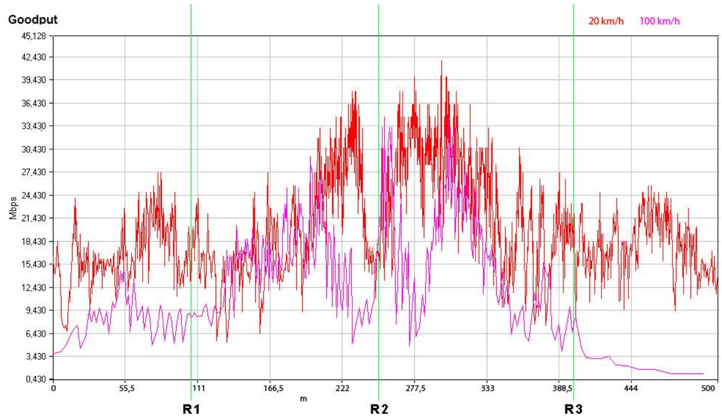

Figure 2: Analysis of Goodput (Mbps) at different speeds (20km/h and 100km/h) in short range drive-thru vehicle network with 802.11n standard.

The graph in Figure 3 shows goodput dependence on speeds of drive-thru vehicle (40km/h, 60km/h and 80km/h) with 802.11n standard.

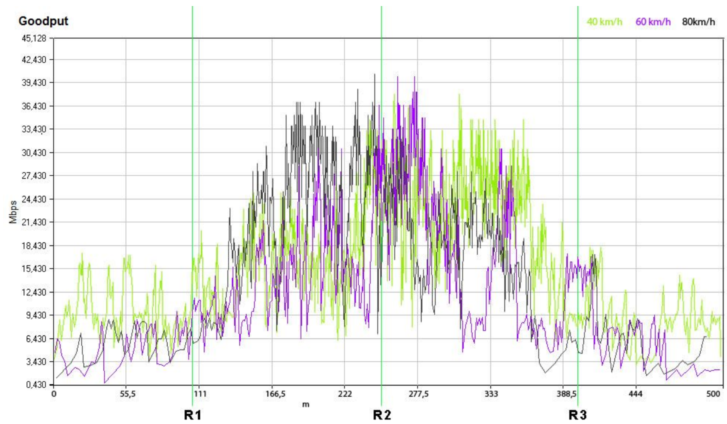

Figure 3: Analysis of Goodput (Mbps) at different speeds (40km/h, 60km/h and 80km/h) in short range drive-thru vehicle network with 802.11n standard.

Analyzing these graphs, it can be concluded that by increasing speed of the drive-thru vehicle, goodput reduced slightly, but at the same time it remains stabile. Significant growth of productivity can be seen not only on main Inter-connected roadside access point (APs), but also on secondary Inter-connected roadside access point (APs). Transitional processes during switching between base stations are not seen practically.

Main advantage of the 802.11n standard is stability of data transfer in Drive-thru Internet system at high speed of drive-thru vehicles.

Using Inter-connected roadside access points (APs) with the 802.11n standard, transition between workstations is performed without fading. Average goodput on all stages was 9,838 Mbps.

Figure 4 shows average goodput dependence on 802.11n at different speeds.

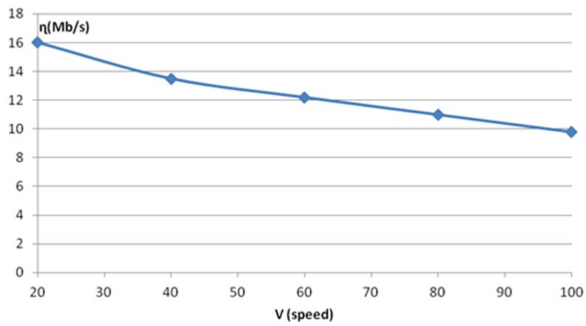

Figure 4: Average goodput dependence on 802.11n at different speeds.

2. Performance Evaluation of Vehicular Heterogeneous Wireless Networks

In second part of report, two-stage real data network and model of network are presented. In this case, differently from first part, server is placed fare away from position of AP concentrator. Therefore additional data transmission channel is solved in network. In our experiments LTE channel has been used.

The physical realization of communication for the transmission data from the vehicle to the user's server and back is the wireless network. At the first stage the data are transmitted from the mobile object to the nearest Access Point according to the protocol 802.11n.

However, the distance from the AP object should not exceed 200 meters. Further, from the AP the data are transmitted to the remote base station (server) by the channel according to the LTE. This variant provides the data transmission at the distance up to the several kilometers. Thus, the object of the research represents the two-stage system of the wireless networks. This system can be represented by the two-stage network model, as it is shown in Figure 5. The null node stimulates the data transmission from the movable object with the intensity of the data transmission ε_0.

The second node stimulates the AP wireless network providing the data reception and transmission from the mobile objects of the null node. The intensity of the data processing is equal to ε_1.

$$\varepsilon_1 = \beta_i, \tag{1}$$

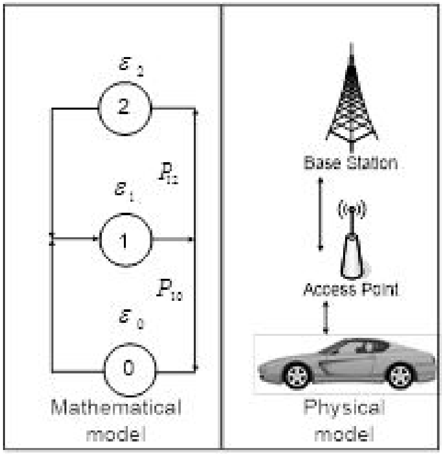

Figure 5: Two-stage vehicular network model.

where β_i – transmission rating in the wireless network 802.11n depending on the distance to the base station as it is shown in the Figure 5.

In order to determine the model parameters, such as the intensity of processing in nodes and transition probability, it is necessary to evaluate the physical parameters of prototype. For the purpose of creation of such prototype was used the equipment of the company Cisco. Using Cisco equipment was built the wireless two rank transport networks.

This prototype represents 'test-bed' for the research of dependence goodput on the travel speed of the vehicle. Moreover, the measurement of useful data transmission rate covers not only the first rank of the system: "mobile object" – AP and further the data transmission channels from AP to the remote server of the user.

Naturally, that the Goodput to a great extent will depend on the data transmission rate from the AP to server, i.e., from the transmission data characteristics. To carry out such researches has been taken the router CISCO C819 M2M which has two output channels. One channel provides the data transmission in GPRS mode. The second channel, being characterized by a high data transfer rate, uses LTE mode — the mode of the next generation of mobile communications. Scheme "test-bed" is presented below (see Figure 6:

The main task in this experiment is the approximate data transmission speed in accordance with the distance to the base station, as well as the second task should be resolved, when the Internet speed should be fixed in accordance with the N moving objects, which are located in the coverage of the wireless network base station.

In order to carry out such study, the program IxChariot should be used. Over the FTP protocol the file is being sent via base stations from the computer to the remote server moving along the base station. FTP protocol is being used to transfer large amounts of data. During the experiment, the actual speed Goodput will be measured

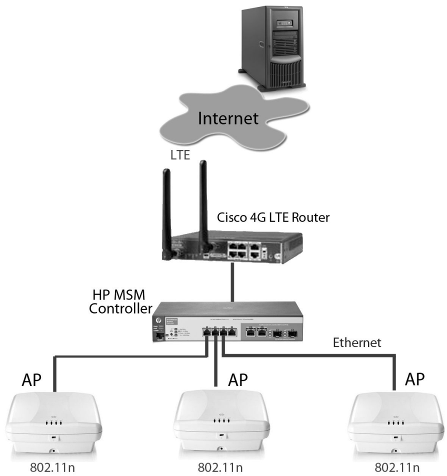

Figure 6: Two-stage network model.

(the recommended data transmission speed) in the program over FTP protocol in order to determine the data transmission speed at the speed of the certain vehicle.

The first experiment was carried out with the use of access point in each direction at the distance of 100 meters from the controller in accordance with the principle as shown in the scheme. This means that the access points are located at the distance of 100 meters from one another, we use three access points and the client was moving with a speed of 20 km/h. It should be mentioned that these experiments have no authority controllers. Goodput - permeability and Elapsed time are denoting the experimental measurement time (see Figure 7).

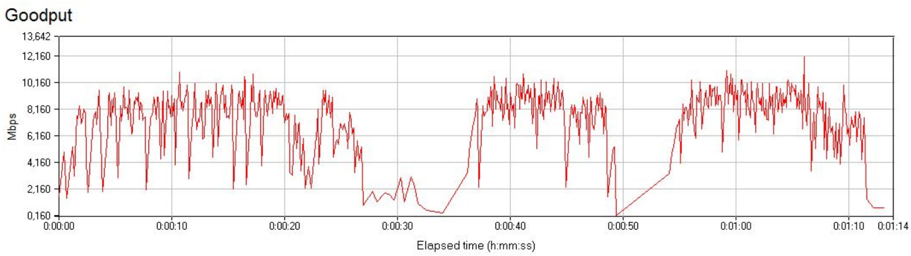

Figure 7: Two-stage goodput with 4G and 802.11n at the speed of 20km/h.

Response time from the device, seconds and Elapsed time are denoting the experimental measurement time (see Figure 8).

The next experiment was carried out at the speed of 50 km/h (Figure 9), traveling down the road along the access points. The distance between the access points is 100 meters. The Figure 10 shows the goodput at the speed of 90 km/h.

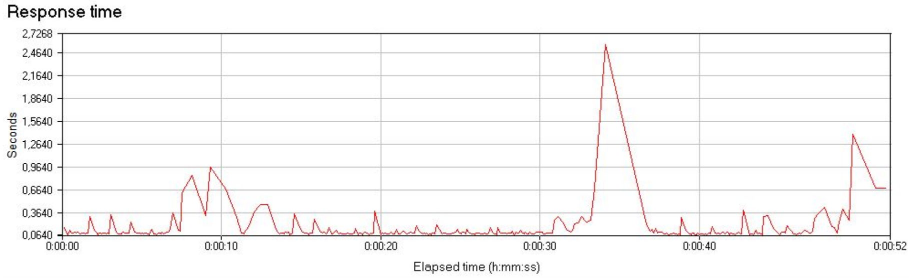

Figure 8: Response time at the client travel speed of 20 km/h along the access points.

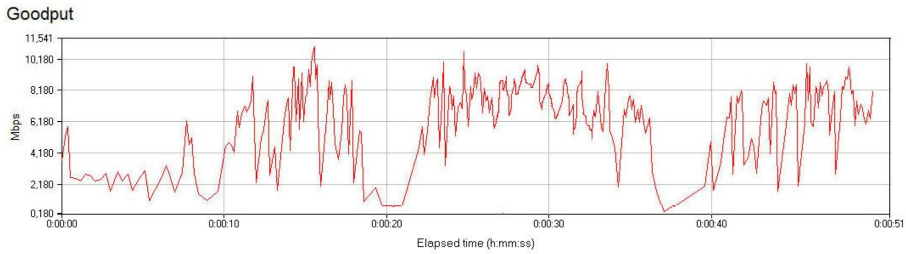

Figure 9: Two-stage goodput with 4G and 802.11n at the speed of 50km/h.

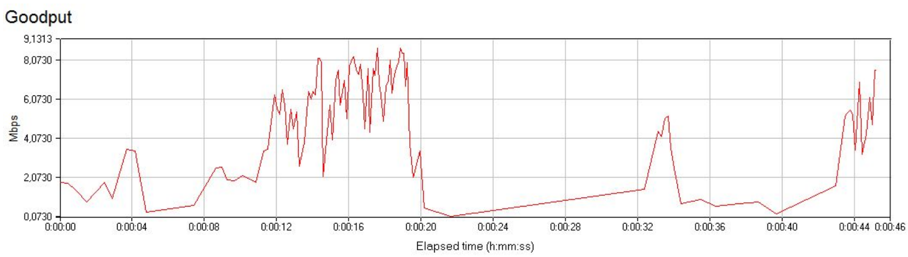

Figure 10: Two-stage goodput with 4G and 802.11n at the speed of 90km/h.

After experimental evaluation main parameters of network, let us return to another ones in model. Depending on the vehicle's proximity to the base station, the data processing rate and data processing intensity in the base station will be different. For the file transfer with packet length of 1500 bytes, the base stations goodput β_i was estimated experimentally.

In its turn, AP is connected with the remote base station along the wireless network with the LTE. The intensity of the data transmission of the second node is to be taken to be equal to ε_2.

The route of the data transmission keeps the track from the null node to the first node and then to the second one [1], if the file transfer is considered from the vehicle to the BS. From the BS it is transmitted the ACK confirmations on the packet's transmission. In this case, the average time for the transmission will be different: more time is spent on the transmission of the data packets, which is denoted as $E(t_i)$

The ACK transmission takes less time and denotes it as $E(t_0)$. Then the average time of the data processing in the zero node will be:

$$E(t_1) = \frac{E(t_i) + E(t_0)}{2}. \tag{2}$$

If on the top of each transmitted packet the ACK confirmations are received, the intensity of the processing in the zero node will be:

$$\varepsilon_0 = \frac{1}{E(t_1)} \tag{3}$$

The model is present in the parameter N, determining the number of the data transmission initiators, which compete for the resource sharing of the 1 and 2 nodes [2]. In our case this is the number of automobiles in the AP coverage area. Then the three-node and two-stage model of the goodput can be expressed by the (12) formula. In this formula the parameters a, X_1 and X_2 are determined by the value from (4).

The valuation problem of the goodput provided by the model consists of the determination of the value N -– the number of vehicles in the AP coverage area. Moreover, in the wireless network standard 802.11n the speed of data transmission depends on the remoteness of the vehicles from AP. The terminal count in each vehicular wireless network is usually high [3, 4]. The bandwidth equation for a two-stage network being:

$$X_1 = \frac{\varepsilon_0}{\varepsilon_1 P_{10}}; X_2 = aX_1; a = \frac{\varepsilon_1}{\varepsilon_2} P_{12}. \tag{4}$$

The intensity for the ε_2:

$$\varepsilon_2 = \frac{1}{t} \tag{5}$$

$$t = \frac{l_p}{V_f} \tag{6}$$

Where V_f – the effective data transfer rate for the LTE. For the having the peak transfer rate V_n. The actual speed is determined in the following way:

$$V_f = \frac{V_n}{2} \tag{7}$$

The starting point for the calculation is the normalizing function $G(N)$, that is chosen from the principle of the sum of probabilities being one $p(n_0, n_1, n_2)$, where n_i in vector $\bar{n} = (n_1, n_{2,3})$ is the inquiry count in i-th node. The resulting equation for $G(N)$ calculation looks like this:

$$G(N) = \sum_{\bar{n}} \prod_{i=1}^{3} (X_i)^n i, \tag{8}$$

$$\bar{n} \in \left\{ n_1, n_2, n_3) / \sum_{i=1}^{3} n_i = N, n_i \geq 0 \forall i \right\}. \tag{9}$$

Where N – the number of vehicles.

The function of the studied two layer vehicular network looks like this:

$$G(N) = \frac{1}{1-a} \sum_{j=0}^{N} X_1^j (1 - a^{j+1}) \tag{10}$$

The Goodput η of the two-stage network is defined as the count of the processed inquiries in per unit of time [4, 5]. The finished task is put out trough the subsystem of input/output, and instantly a new task is loaded through it. The probability of a lack of inquiries in the i-th node will be [6, 7]:

$$p\{n_i = 0\} = \frac{G(N) - X_i G(N-1)}{G(N)} \tag{11}$$

The result is:

$$\eta = P_{10} \varepsilon_1 (1 - p\{n_i = 0\}) \tag{12}$$

The particular importance is paid to the assessment of parameter N – the number of "tasks" or requests, circulating in the network of communication [4, 11]. Taking into the consideration the fact that the number of mobile customers in the coverage area of the base station WiFi is limited or fixed, and then the model corresponds to the class of closed networks of queuing system [9, 10].

If, the average number of customers N_n, who present in the coverage area of the base station and the average number of packages Z received or transmitted by the customer in the base station can be determined and the number of inquiries in the network is:

$$N_n = N \cdot Z \tag{13}$$

For the determination the number of customers in the coverage area of the base station will be consider the highway on which there is a high way flow of cars – the worst case for the researched network [12]. Such high rate flow according refers to the class of mobile objects, following for the leaders. It has been affirmed that the distribution of time intervals for the consecutive vehicles can be approximated by the Erlang distribution of $(k-1)$ order.

According to an experimental data this value lies within the range of 5 to 7 . The intensity of input flow of vehicles:

$$\lambda_2 = \frac{1}{\overline{h_2}}, \tag{14}$$

where $\overline{h_2}$ – is the average value of the interval between the vehicle and the distribution of intervals itself between vehicles:

$$f(h_2) = \frac{(K\lambda_2)^K \cdot h_1^{K-1} \cdot e^{-\lambda_2 K h_2}}{(K-1)!}. \tag{15}$$

Erlang law of $k - 1$ law is formed as a chain of stages on which occur the delays of requests, distributed exponentially with parameters $\lambda_2 K$.

The intensity of traffic of automobiles, passing through any given point of the road per unit time [8], including the location point of the base station constitutes:

$$q = K\vartheta. \tag{16}$$

According to some experimental data the intensity of traffic is 1800-1900 of vehicles/per hour for traffic lane [13]. Naturally, if the number of bands in one direction, then the service rate of vehicles will be z times more, i.e.

$$q_z = K \cdot z. \tag{17}$$

At that it is necessary to take into the consideration the density of vehicles per unit of length of band [14]. In this case the unit of length constitutes the diameter of coverage area of the base station – 200 meters.

The given initial data allow coming to the estimation of the average number of vehicles on the road [15]. For this we assume that the ingoing stream of automobiles Erlang $k - 1$ order and $k = 5$. The service time of flow of vehicles of the road with the bands is a random value of distribution on exponentially law with the parameter q_z.

For the evaluation the number of vehicles which are in the coverage area of the road, use the $E_k/M/1$ model. According to the number of customers in the system of service, i.e., the average number of vehicles in segment of road:

$$L = \frac{\rho}{1 - r_0^k}. \tag{18}$$

Where ρ – the load ratio of the system.

In our case:

$$\rho = \frac{\lambda_2}{q_z}. \tag{19}$$

At that there r_0 is a root of solution of characteristic equation which lies in the interval 0,1.

$$q_z \cdot r^{k+1} - (k \cdot \lambda_2 + q_z)r + k\lambda_2 = 0. \tag{20}$$

In the considered situation $k = 5$. Note that r_0 is comparable with ρ, then the solution (20) for r_0 is sought iteratively. In the Table 1 are presented the results of

ρ	0.25	0.5	0.6	0.75	0.8	0.9
r_0	0.56	0.76	0.84	0.88	0.9	0.92
$L = N$	0.265	0.67	1.031	1.588	1.954	2.64

Table 1: The number of vehicles on the road section.

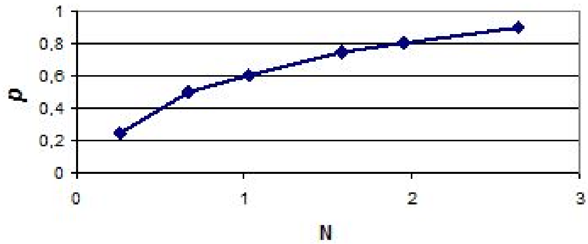

Figure 11: The number of vehicles with the different load factor ρ.

solution of equation for the different load factors as well as the resulting indices of number of vehicles on the road section included in the service area of the base station (see Figure 11).

From the equation (12) for each segment can be calculated. The network performance influences the probability of transmission of the confirmation ACK, as increases, the number of packages per unit of time increases too.

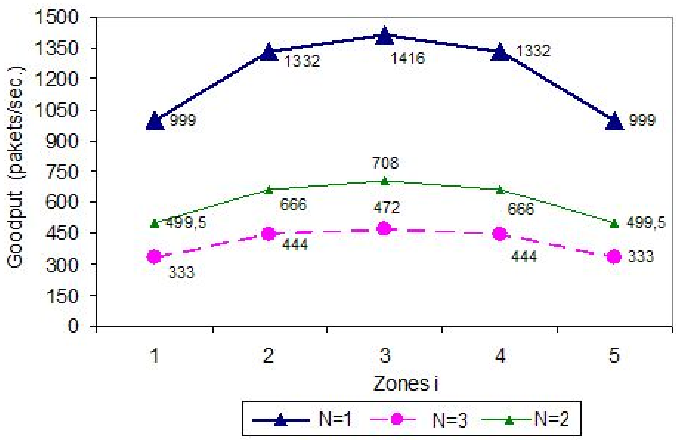

Figure 12: Goodput for two-stage network model with P_{10} = 0.999, P_{12} = 0.001 for 802.11n and LTE at the Erlang distribution.

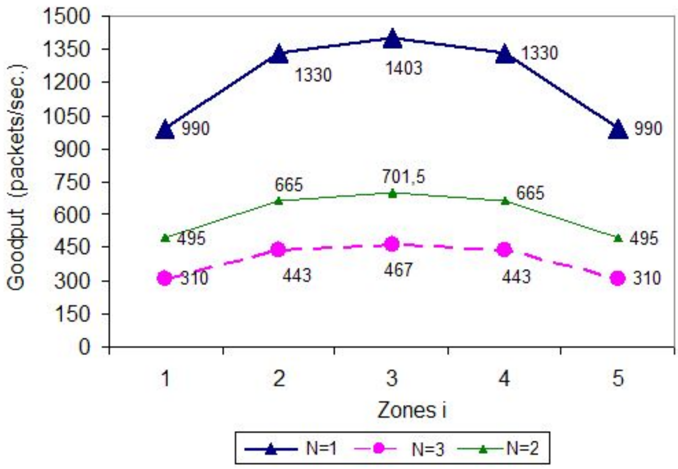

Figure 13: Goodput for two-stage network model with $P_{10} = 0.99$, $P_{12} = 0.01$ for 802.11n and LTE at the Erlang distribution.

3. Conclusion

In fact, we have derived practical analytical models for the distribution of the number of packets that a vehicle can download from a two-stage network system with access point and base station. In this work was developed the model to determine the actual speed of date transmission, depending on the number of mobile objects.

On the basis of obtained data it is possible to conclude that the performance of the base station is connected both with the traffic parameters and data transmission feature. In this paper were developed the model for the determination of the actual speed of data transmission, depending on the number N of the mobile objects, which are in the coverage area of the base station of the wireless network. On the basis of the paper the actual rate of datatransmission will depend on the number of objects, interacting with the base station and their remoteness from it.

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