ROAD TRAFFIC NON-STATIONARY ANALYSIS OF THE VEHICULAR WIRELESS NETWORK GOODPUT EVALUATION

Nikolajs BOGDANOVS, Ernests PETERSONS
Department of Transport Electronics and Telematics, Riga Technical University, Riga, Latvia

***Abstract*:** this article suggests the creation of transport wireless network. For system behavior analysis in transitive non-stationary operating mode we will use diffusion approximation method. In the given work server non-stationary operating mode at near to self-similar query stream influence is considered with the main accent on server relaxation time. In this case the model for research is cyclic closed network model consisting of terminal system and a network server which common solution has been developed by H. Kobayashi [1].

***Keywords*:** Network model, IEEE 802.11n, non-stationary mode.

1. Introduction

In this work non-stationary of vehicular movement on roads is discussed and analyzed. And main 'goal' of this analyzing is evaluation number of vehicular units in wireless network roadside Access point coverage range.
Roadside Access Point may be use along roadside for providing moving user's multiple-access to Drive-thru Internet system. For this reason WiFi technology may be utilized.
The main questions in realizing Wireless technology are connected with network goodput evolution. The Goodput and Throughput depend not on wireless channels and data transmission speed, but also on the number of Access Point clients (vehicles in AP coverage range) [2].
The number of concurrent vehicles in the coverage rank depends on the vehicle speed, vehicles density on roads and on the regime of road traffic.
There may be two regimes – stationary regime which may be proposed to us by the vehicle flow on the long main roads and the non-stationary regime.

2. Experiment

These experimental data were used in order to estimate the number of cars in AP area in stationary mode.

The experimental results presented in the paper were used for the estimation of the actual speed of data transmission between the moving vehicle and the base station if operating takes place in the mode of a file transfer according to the ftp protocol. The File Transfer Protocol (FTP) is a standard network protocol used transferring files from one host over a TCP-based network, such as the Internet [3]. The Ftp protocol is meant for the transmission of the large-size files. During the experiment the actual, effective speed of data transmission was measured in the Goodput with the protocol ftp, determines the data transmission rate of the large volumes. In networks, the Goodput is the application level throughput, being a ratio between the delivered amount of information and the total delivery time.
The estimation was made by the means of IxChariot software [1] [4] To estimate speed of data transfer the "Goodput" scenario was used.#. The main feature of this estimation is the fact of speed measurement of the data transmission depending on the remoteness of the mobile object from the base station and its moving speed. The base stations are connected with the primary station, using WDS (Wireless Distribution System) connection Fig.1.

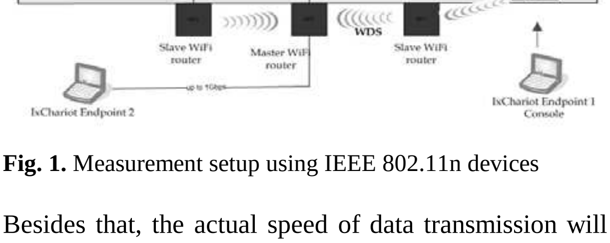

Fig. 1. Measurement setup using IEEE 802.11n devices

Besides that, the actual speed of data transmission will depend on the number of objects, which are in the coverage area of the station [3], supposing that the average length of the automobile is 5 meters and the necessary distance on the road between automobiles is also 5 meters.

By analyzing our previous researches on the vehicle distribution in the area of the base station (200 metres) [1], we can conclude that the process of vehicle distribution is not well-established as the vehicle speed is not constant. Therefore, in order to find out when the distribution process becomes stationary, it is necessary to use the diffusive approximation.

3. Stationary regime analyses

The given work pays attention to the relaxation time. In this case the model for research is the cyclic closed model consisting of the terminal system and the network server [4] (Fig.2):

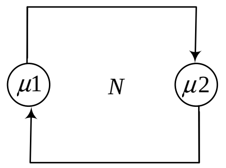

Fig. 2. Cyclic closed network model

In article [1], for determining the vehicles numbers investigate a closed network consisting of M independent nodes with N incoming customers is investigated. We take into consideration that the parameter ϖ_i according to the highway speed on the movement during highway is characterized by density [2] [3]. The customer service intensity ϖ_i in zone i is related to the length of zone and the vehicle (customer) velocity in zone.

If the zone length equals to S_i, and vehicle movement speed equals to ϑ_i, then the intensity of vehicle service by road interval equals to [8]:

$$\varpi_i = \vartheta_i / S_i \qquad (1)$$

According to (1) the intensity of vehicle service is depends on the initial vehicle flow rate during the road interval and on the density of vehicle location on the road interval.

In fact, to determine the growth of the speed of the vehicle the experiment was made and its results are present in Fig.3.

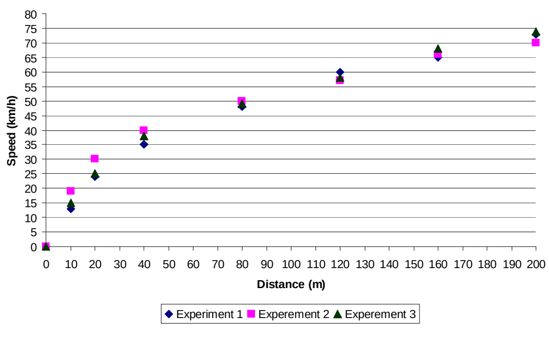

Fig. 3. Speed of vehicle

Fig. 3 shows the transport speed at the distance of 200 meters, as well as the calculation of the time, which is necessary to overcome each subarea of 40 meters of the total area: Captions of figures should be aligned with both edges of the column below the figures, in 9-point font, single spacing.

Table 1. Average time of overcoming for zone (40 meters)

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
3.6 seconds	2.3 seconds	1.9 seconds	1.7 seconds	1.6 seconds

The constant transport speed is 100km per hour.

$\vartheta_{200-600} = \dfrac{100000m}{3600s} = 28m/s$, so, in order to overcome the area of 400 meters, 14 seconds are necessary.

3. Mathematical model for non-stationary regime

The overall number of queries circulated in the system is equal to N. Thus, we have the closed loop system. This model can be considered as an equivalent of the server model with the limited N size of buffer memory queries their which accept a stream of queries on their input [1].

The query stream can be arbitrary, and intervals characteristics between queries are defined only by the first moment μ_2 and dispersion σ_2^2 of the returned to the terminal system queries processing.

It is known, that one of the self-similar traffic models is the stream of queries, whose arrival time intervals fit so called power-tail distributions. One of the important characteristics of these distributions is the dispersion tending to infinity and one of the popular laws for such intervals description is Pareto distribution. The probability density of random variable x in this law can be defined by the expression:

$$f(x) = \frac{\alpha}{k}\left(\frac{k}{x}\right)^{\alpha+1} \qquad (2)$$

Here x > k and k > 0. If $\alpha \le 2$ then $\sigma^2 \to \infty$ but when $\alpha \le 1$ both mean and dispersion are tending to infinity. In work used by authors it is impossible to emulate strictly Pareto law for query intervals distribution description. However, this research carried out the increase of dispersion, and, consequently, also the variation coefficient $C = \sigma^2 / m^2$, where m is query mean time. This research assumed that the mean is limited, but the dispersion increases, coming nearer to very great value as it takes place in the self-similar traffic. This is the essence of the term "near to self-similar" in the name of given article.

The considered work insists that in the terminal system $\sigma_2^2 \to \infty$, and $\mu_2 = const$. The outgoing stream of such node, and, hence, the incoming stream of the server, will be close to self-similar. Input of this system is a Poisson stream with mean service time μ_1 and the terminal system load coefficient Ψ .

Let's imagine a cyclic system where processing time on terminal i is subordinated to the distribution law with the mean μ_i and the variation coefficient C_i where i=1, 2. The system is loop-closed, therefore N is a total query quantity in the system, N=const. Let's define diffusion process which approximates the queue length $n_1(t)$ through x(t).

Then corresponding diffusion equation will look like this:

$$(\partial/\partial t)\rho(x_{0,}x;t) = \frac{1}{2}\alpha^o(\partial^2/\partial x^2)\rho(x_{0,}x;t) - \beta^o(\partial/\partial x)\rho(x_{0,}x;t) \quad (3)$$

Where $\alpha^o = C_1/\mu_1 + C_2/\mu_2$ and $\beta^o = 1/\mu_2 - 1/\mu_1$. Solving this equation with boundary conditions $0 \le x(t) \le N+1$ for all $t \ge 0$ use scaling transformation:

$$y = \frac{x}{|a^o/b^o|} = \frac{x}{|(C_1 + C_2\rho)/(1-\rho)|} \quad (4)$$

$$\tau = \frac{t}{|a^o/b^o|} = \frac{t}{\mu_1}(C_1 + C_2\rho)/(1-\rho)^2 \quad (5)$$

Where $\rho = \mu_1/\mu_2$. As a result we have coordinate-free diffusion equation:

$$(\partial/\partial\tau)\rho(y_{0,}y;\tau) = \frac{1}{2}(\partial^2/\partial y^2)\rho(y_{0,}y;\tau) - \delta(\partial/\partial y)\rho(y_{0,}y;\tau) \quad (6)$$

With two reflecting barriers y=0 and y=b:

$$\frac{1}{2}(\partial/\partial y)\rho(y_{0,}y;\tau) - \delta(\partial/\partial y)\rho(y_{0,}y;\tau) = 0 \quad (7)$$

Where $\delta = 1 if \rho < 1, 0 if \rho = 1, -1 if \rho > 1$ and

$$b = \frac{N+1}{|(C_1 + C_2\rho)/(1-\rho)|} \quad (8)$$

Applying the method of "eigenfunction expansion", we obtain the following solution for:

$$\rho(y_{0,}y;\tau) = \frac{2\delta e^{2\delta y}}{e^{2\delta b}-1} + \exp\left[\delta(y-y_0) - \frac{\delta\tau}{2}\right]\cdot\sum_{n=1}^{\infty}\Phi_n(y)\cdot\Phi_n(y_0)\cdot\exp\left[-\frac{\lambda_n^2\tau}{2}\right] \quad (9)$$

Here $\Phi_n(y)$ and $\Phi_n(y_0)$ are eigenfunctions associated with eigenvalues λ_n :

$$\Phi_n(y) = \left(2\lambda_n^2\cdot b(\lambda_n^2+1)\right)^2\cdot\left(\cos\lambda_n y + \frac{\delta}{\lambda_n}\sin\lambda_n y\right) \quad (10)$$

Where $\lambda_n = n\pi/b$ and n=1, 2, 3... .

The first term of (9) represents the steady-state probability and the second term gives the transient part in terms of eigenfunction expansion. Note that (9) satisfies the initial condition $y = y_0$ i.e. $\rho(y_o, y;\tau) = \delta(y - y_0)$, since the delta function is expressed in terms of the eigenfunctions. The second term of (9) is an infinite series, but can be well approximated by finite terms, since the factor $\exp(\lambda_n^2\tau/2)$ approaches zero as n increases.

As the starting point allows to take parameters C_1 and C_2 equal to 1 and server load coefficient $\rho = 0.75$ (Fig.4).

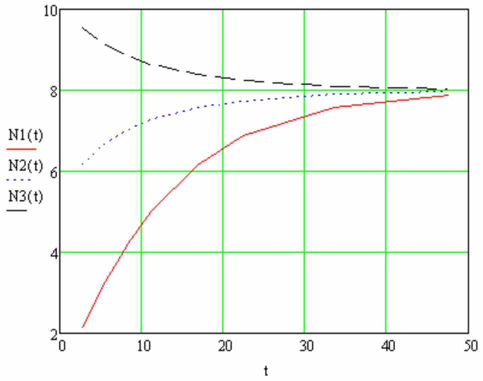

Fig. 4. Mean number of queries in the system at the load 0.75 with Poisson query stream

Here n1, n2 and n3 are server queue lengths with different initial conditions – when initial queue length is 0, N/2 and N correspondingly. Checking this result (with exponentially distributed server and the terminal system service times in stationary mode) with the result obtained using well known methods we can say that this model gives similar results and can be used for the further researches. Now let's increase C_2 significantly to emulate self-similarity of the traffic but still leaving C_1 equal to 1.

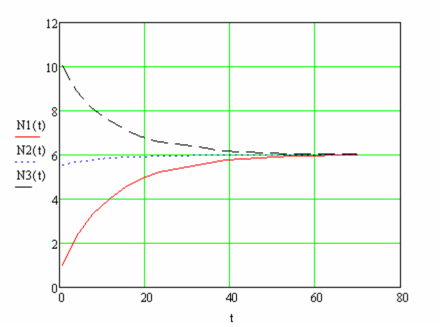

Fig. 5. Mean number of queries in the system at the load 0.95 with Poisson query stream

The resulting data are comparable to the diffusive approximation schedule under the load of 0.75 and 0.95 (Fig.4 and Fig.5). Further we try to apply more or less real wireless network parameters to the above model. As real data speed in the wireless networks is known to be much less, we assume that the real data speed is half of that proclaimed by standard. We also assume that network is homogeneous – wireless clients are also equal to 802.11n. The following situation is assumed. The graph shows that, depending on the loading factor, the number of users varies in time and the stationary mode appears after 60 seconds. For checking purposes the same two-node system in the stationary mode can be used. The bandwidth equation for a two-node network:

$$X_1 = 1, X_2 = \frac{\mu_1}{\mu_2}, G(N) = \frac{N_2^{N+1} - 1}{X_2 - 1} \quad (11)$$

The output flow is equal to input flow and from this rule of flow balance it is possible to write the equation. The number of vehicles is being calculated as follows:

$$n = \frac{N+1}{(1 - X_2^{N+1})} - \frac{1}{(1 - X_2)} \quad (12)$$

Let's compare the obtained results with the results of the diffusive approximation (Table 2):

Table 2 Comparative results

p	Diffusive approximation	Cyclic queuing model
0.75	8	7.485
0.95	6	5.51

The Table 2 shows that the diffusive approximation is correct.

5. Comparative analyses two calculations

The average number of queries (vehicles) in i-th interval for stationary regime as shown in Table 3.

$$E\left[n_i\right] = \sum_{K=1}^{M} (x_i)^K \cdot \frac{G(N-k)}{G(N)} \quad (13)$$

Where G(N) is the normalizing constant, resulted from equalizing to one of all the probabilities of the system states[2][4]. Naturally, there are no limitations for the number of vehicles (queries) in the i-th interval.

Table 3 Average number of queries for stationary regime

Vehicle	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Loading 0.95					
10	5.81	1.03	0.92	0.76	0.69
20	15.69	1.65	1.04	0.85	0.76
Loading 0.75					
10	4.36	0.77	0.69	0.57	0.52
20	11.77	1.24	0.78	0.64	0.57

Table 4 calculates the number of automobiles in every sub-zone AP according to *x* y from time as well as according to 2 values of loading 0.75 and 0.95.

Table 4 Average number of queries for non-stationary regime

Vehicle	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Loading 0.95					
10	5.25	1.03	0.92	0.76	0.69
20	14.56	1.65	1.04	0.85	0.76
Loading 0.75					
10	3.94	1.03	0.917	0.761	0.689
20	10.91	1.24	0.78	0.64	0.57

6. Conclusions

For non-stationary regime of the transport traffic flow it is necessary to use the differential approximation of the automobiles number in AP action sub-zone. On the basis of the obtained data, we can conclude that the diffusive approximation can be used to determine the amount of traffic.
This paper presents the diffusive approximation with the load of 0.75 and 0.95. The graphs show the time, when the distribution process of vehicles will become stationary. On the basis of this work, the distribution process will become stationary under exponential law.

7. References

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