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Server non-Stationary Behaviour Research at Near to Self-Similar Query Stream Influence

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Introduction

Research of various network traffic types proves that it is self-similar. Therefore, recently many works and fundamental monography is devoted to its research [3]. Self-similar traffic influence on communication devices, such as network switchboards, concentrators and network servers, lead to sharp decrease in their functioning quality, comparing to operating mode in conditions of traditional streams of packets and queries. It reveals in throughput reduction of network nodes, insufficiency of buffer memory and increase of denial of service stream. Usually all researches of self-similar traffic influence were made in stationary operating mode of switched devices.

Authors of the given work observed not less interesting displays of self-similar traffic at inclusion of communication devices in work, when load swing arise and certain time - relaxation time - was required for device to enter into a normal stationary operating mode.

Therefore in the given work the attention is given to a non-stationary operating mode of communication devices.

In this case the model for research is cyclic closed model consisting of terminal system and a network server which common solution has been developed by H. Kobayashi [2]. The model has been modified with the purpose of creation a stream of queries to a server which is coming nearer to self-similar.

As a result of research data about transient process durations, utilization of buffer memory and probability of incoming query denial of service depending on server load have been obtained.

Mathematical model

For system behavior analysis in transitive non-stationary operating mode we will use diffusion approximation method. The choice of this research method is caused by fact that imitating modeling of communication systems at self-similar traffic influence demands very big time for modeling [1] and not always leads to unambiguously interpreted results. Therefore H. Kobayashi work has been taken as a basis for this research.

Communication system model is presented in the form of a server, which has intensity of query service equal to μ_1. Terminal subsystem sends queries to server input. Queries processed by server come back to the terminal system which processes them with intensity μ_2. Overall number of queries circulating in the system is equal to N. Thus, we have closed loop system. This model can be considered as an equivalent of server model with limited N size of queries buffer memory, which accepts a stream of queries on its input.

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 returned to the terminal system queries processing.

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

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

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 strictly emulate Pareto law for query intervals distribution description. However, in this research was carried out the increase of dispersion, and consequently also variation coefficient $C = \frac{\sigma^2}{m^2}$, where m is mean of intervals between queries. In research it was assumed, that mean is limited, but dispersion increases, coming nearer to very great value as it takes place to be in self-similar traffic. This is the essence of the term "near to self-similar" in the name of given article.

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

Let's imagine a cyclic system where processing times on terminal i are subordinated to distribution law with mean μ_i and variation coefficient c_i, *i=1,2*. System is loop-closed, therefore N is total query quantity in the system, N=const. Let's define diffusion process which approximates queue length $n_1(t)$ through *x(t)*. Then corresponding diffusion equation will look like

$$(\partial/\partial t)p(x_0,x;t)=\frac{1}{2}\alpha^\circ(\partial^2/\partial x^2)p(x_0,x;t)-$$

$$-\beta^\circ(\partial \ /\partial x \ )p(x_0,x;t). \qquad (3)$$

Where $\alpha^\circ = C1/\mu_1 + C2/\mu_2$, $\beta^\circ = 1/\mu_2 - 1/\mu_1$. Solving this equation with boundary conditions $0 \le x(t) \le N+1$ for all $t \ge 0$ use scaling transformation

$$y=\frac{x}{\left|a^\circ/b^\circ\right|}=\frac{x}{\left|(C1+C2\rho)/(1-\rho)\right|},$$

$$\tau=\frac{t}{\left|a^\circ/b^\circ\right|}=t/\mu_1\,(C1+C2\rho)/(1-\rho)^2. \qquad (4)$$

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

$$(\partial/\partial\tau)\rho(y_0,y;\tau)=$$

$$=\tfrac{1}{2}(\partial^2/\partial y^2)\rho(y_0,y;\tau)-\delta\cdot(\partial/\partial y)\rho(y_0,y;\tau). \quad (5)$$

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

$$\tfrac{1}{2}(\partial \ /\partial y \ )\rho(y_0,y;\tau)-\delta\cdot\rho(y_0,y;\tau)=0, \text{ if } y=0 \text{ and } y=b. \qquad (6)$$

Where

$$\delta=\begin{cases}1, & \rho<1,\\ 0, & \rho=1,\\ -1, & \rho>1,\end{cases} \qquad (7)$$

$b=(N+1)/\left|(C1+C2\rho)/(1-\rho)\right|$.

Applying the method of "eigenfunction expansion", we obtain the following solution for (5):

$$\rho(y_0,y;\tau)=\begin{cases}2\cdot\delta\cdot e^{2\cdot\delta\cdot y}/(e^{2\cdot\delta\cdot b}-1)+\exp[\delta(y-y_0-\delta\tau/2]; \\ \sum_{n=1}^{\infty}\Phi_n(y)\cdot\Phi_n(y_0)\exp(-\lambda_n^2\tau/2), \quad 0\le y\le b; \\ 0, \qquad \text{if y > b}\end{cases} \quad (8)$$

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

$$\Phi_n(y)=\left[2\lambda_n^2\cdot b(\lambda_n^2+1)\right]^2\left\{\cos\lambda_n y+(\delta/\lambda_n)\sin\lambda_n y\right\} \text{ и}$$

$$\lambda_n=n\pi/b, \text{ a } n=1,2,3,\dots.$$

The first term of (8) represents the steady-state probability and the second term gives the transient part in terms of eigenfunction expansion. Note that (8) satisfies the initial condition $y=y_0$, i.e. $\rho(y_0,y;\tau)=\delta(y-y_0)$, since the delta function is expressed in terms of the eigenfunctions. The second term of (8) 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.

Average number of queries and denial of service probability

Let's present research results of an average number of queries and query denial of service probabilities depending on time of transient.

Let's consider a case when utilization factor is equal to $\rho=0{,}75$. Fig. 1 shows dependence of number of queries in the buffer and Fig. 2 – denial of service probability.

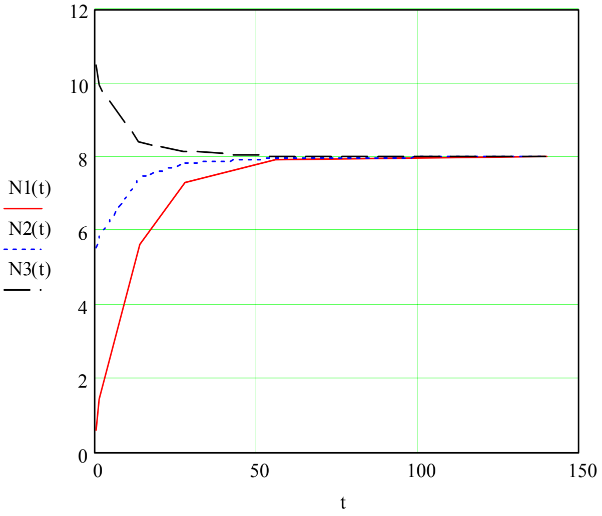

Fig. 1. Number of queries in the buffer, *C1=C2=1,* $\rho=0{,}75$

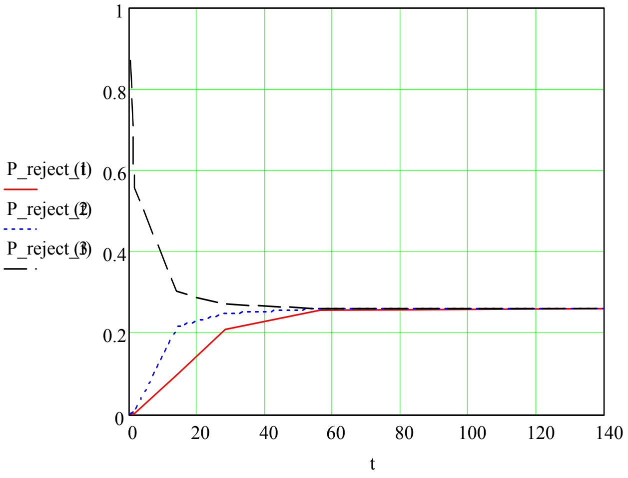

Fig. 2. Denial of service probability, *C1=C2=1,* $\rho=0{,}75$

And now, for contrast, we will show a picture of transient for *C2=50* (Fig. 3, 4).

Note, that in figures for presentation the smoothed curves without oscillatory processes which actually take place are shown. In all figures three curves corresponding initial distribution of number of queries between a server and terminal system are presented.

Now let's address to the graphs describing behaviour of analyzed parameters when $\rho=0{,}95$.

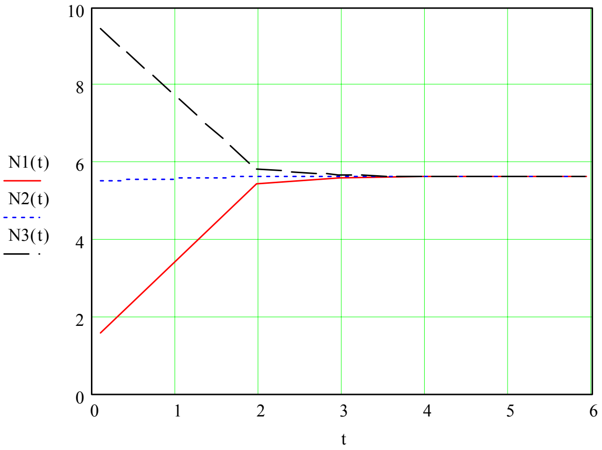

Fig. 3. Number of queries in the buffer, *C1=1, C2=50,* $\rho = 0{,}75$

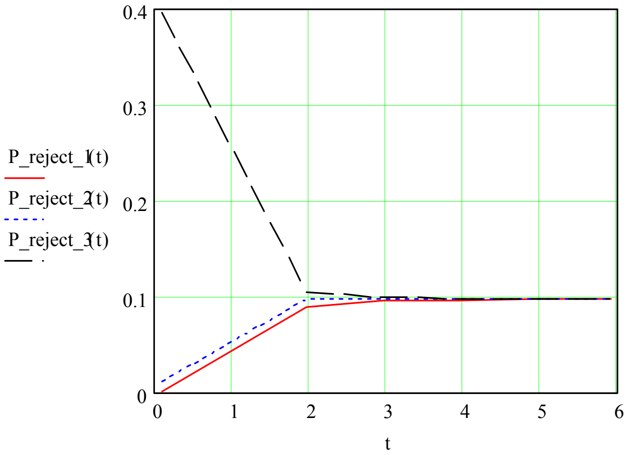

Fig. 4. Denial of service probability, *C1=1, C2=50,* $\rho = 0{,}75$

In Fig. 5 we can see number of queries in the buffer and in Fig. 6 denial of service probability. The given graphs concern to a case of the elementary entrance stream of queries.

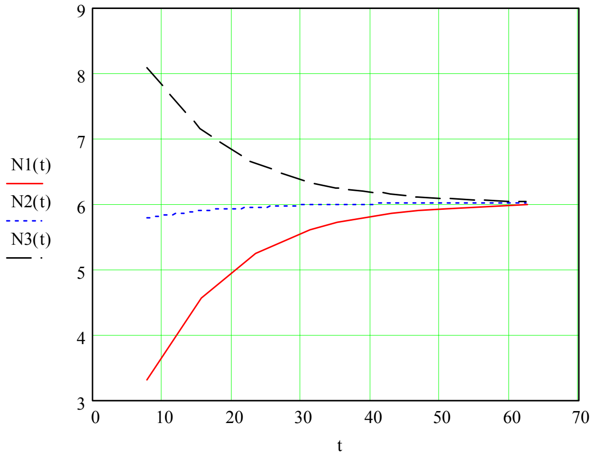

Fig. 5. Number of queries in the buffer, *C1=C2=1,* $\rho = 0{,}95$

For contrast Fig. 7 shows the number of queries in the buffer in a transitive mode, and Fig. 8 shows probability of denial of service when the input stream of queries has the increased dispersion (C2=50) i.e. it's coming nearer to self-similar.

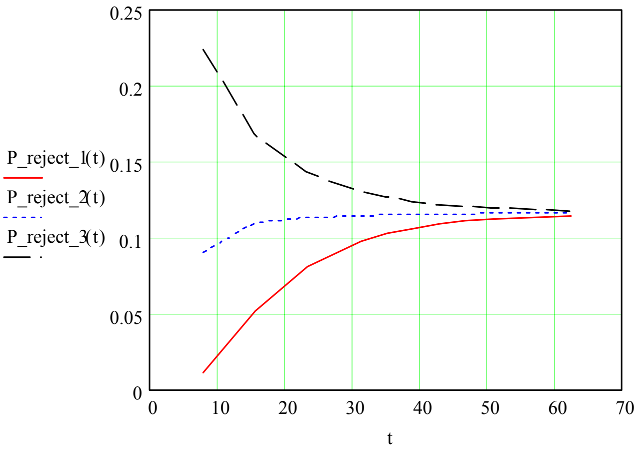

Fig. 6. Denial of service probability, *C1=C2=1,* $\rho = 0{,}95$

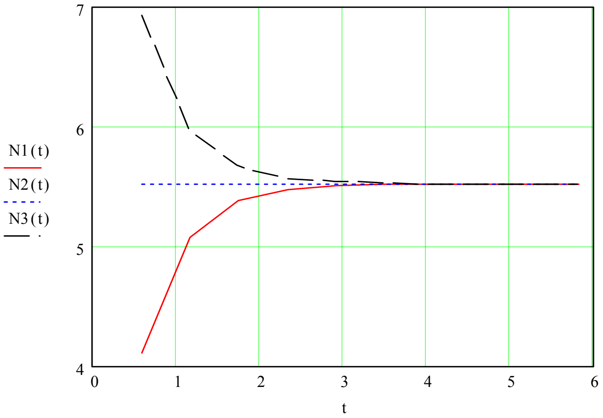

Fig. 7. Number of queries in the buffer, *C1=1, C2=50,* $\rho = 0{,}95$

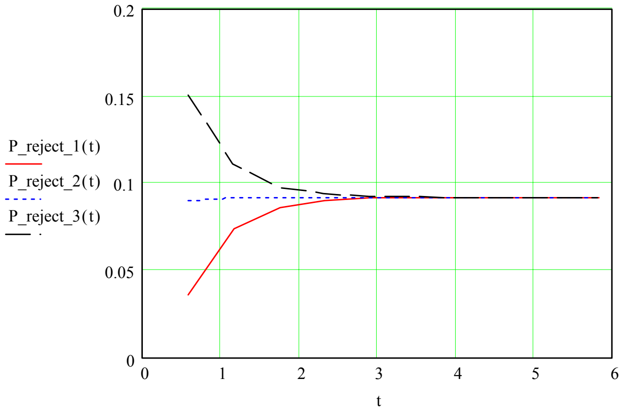

Fig. 8. Denial of service probability, *C1=1, C2=50,* $\rho = 0{,}95$

The obtained results allow to make conclusions on character of behaviour of a server work depending on an input stream variation factor C2 increase, i.e. at its approach the self-similar traffic, characterized by C2 tending to infinity.

Note that in this work $\rho = \dfrac{\mu_1}{\mu_2} < 1$ is the attitude of query processing intensity on a server to intensity of their receipt from terminal system, not the other way, as it is often done!

The general conclusion turns out following: while variation coefficient increases, the average number of.

Table 1. Experimental data

C2	**1**	**2**	**5**	**10**	**20**	**50**
n(*C2*) $\rho = 0{,}75$	*2,26*	*2,81*	*4,286*	*5,6*	*5,61*	*5,63*
n(*C2*) $\rho = 0{,}95$	*2,84*	*3,3*	*4,1*	*5,0*	*5,50*	*5,52*

Table 2. Experimental data

C2	**1**	**2**	**5**	**10**	**20**	**50**
$P_{reject}(C2)\ \ \rho = 0{,}75$	*0,034*	*0,027*	*0,044*	*0,09*	*0,095*	*0,097*
$P_{reject}(C2)\ \ \rho = 0{,}95$	---	*0,012*	*0,036*	*0,068*	*0,091*	*0,092*

queries in buffer memory decreases and for both cases of utilization remains practically identical, even at achievement of variation coefficient equal to 50 (*C2=50*).

Denial of service probability also decreases while C2 increases.

Table 1 shows experimental data about number of inquiries in buffer memory depending on variation factor C2 increase, i.e. at aspiration of the input traffic to self-similarAs we see from the table, the number of queries in buffer memory increases in 2,49 ($\rho = 0{,}75$) and in 1,94 times ($\rho = 0{,}95$) in comparison with a case of the elementary input stream, when C2=1. And, the less productive server is, the greater number of queries stays in buffer memory.

Table 2 shows experimental data about denial of service probability $P_{reject}(C2)$ depending on variation coefficient C2 increase 5 seconds later the server started working.

For the elementary input stream and $\rho = 0{,}95$ it was not possible to obtain the denial of service probability because of its very small value. Therefore let's compare values of denial of service probability for C2=50 in relation to a stream, described by variation coefficient C2=2.

The result of comparison shows that in a transitive mode denial of service probability sharply increases while input stream tends to self-similar, in particular in 3.6 times if $\rho = 0{,}75$ and 7.7 times if $\rho = 0{,}95$.

Let's note thus, that in all researches it was supposed, that query processing time on a server submitted exponential distribution law with characteristic value of variation coefficient C1=1.

Different character of behaviour is marked at $\rho > 1$ (Fig. 9, 10, 11,12).

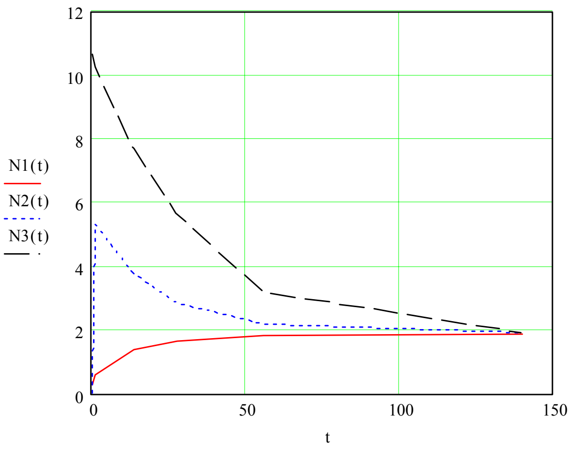

Fig. 9. Number of queries in the buffer, *C1=1, C2=1,* $\rho = 1{,}7$

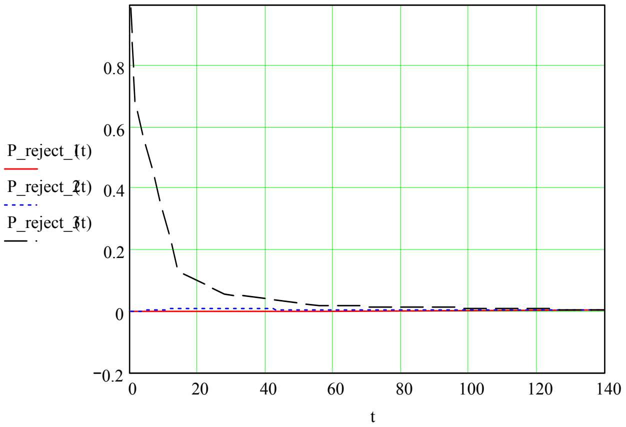

Fig. 10. Denial of service probability, *C1=1, C2=1,* $\rho = 1{,}7$

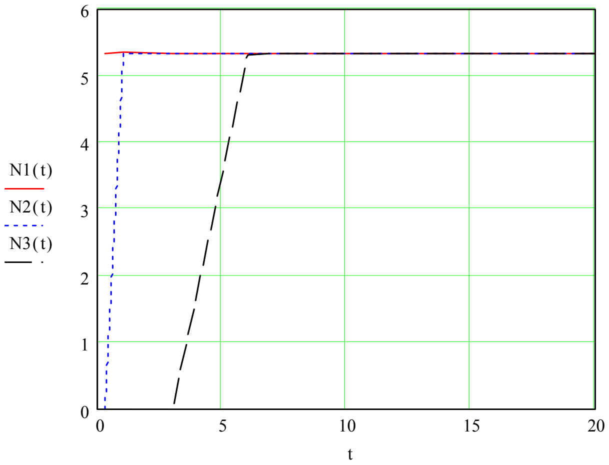

Fig. 11. Number of queries in the buffer, *C1=1, C2=50,* $\rho = 1{,}7$

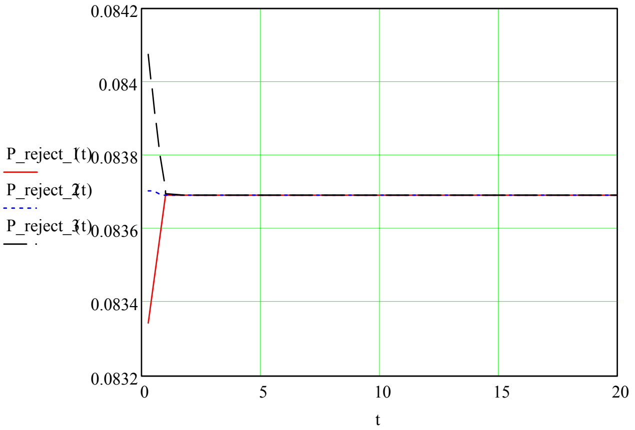

Fig. 12. Denial of service probability, *C1=1, C2=50,* $\rho = 1{,}7$

Conclusions

In this work character of server behaviour in a transitive operating mode at near to self-similar input stream is analysed.

It is revealed, that typical parameters for a server – number of queries in buffer memory and denial of service probability – essentially differ from the similar parameters observed in a stationary operating mode.

In all cases typical parameter values of server work differs from the values in case of server work with elementary query input stream.

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S. Ilnickis, E. Petersons, R. Jerjomins. Serverio nestacionaraus elgesio tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2005. – Nr. 3(59) – P. 46 –50.

Tradiciniai tinklo sujungimų ir apdorojimo įtaisų parametrų tyrimai remiasi elementariaisiais užklausų ar paketų srautų tyrimais. Daugelyje tyrimų parodyta, kad tradicinis priėjimas lemia dideles klaidas nustatant įtaisų parametrus. Ši išvada buvo padaryta remiantis stacionaraus įtaisų funkcionavimo būsenos analize. Straipsnyje įvertinta įtaisų nestacionaraus funkcionavimo būsena, veikiant užklausų srautui. Il. 12, bibl. 4 (anglų kalba, santraukos lietuvių, anglų ir rusų k.).

S. Ilnickis, E. Petersons, R. Jerjomins. Server non-Stationary Behaviour Research at Near to Self-Similar Query Stream Influence // Electronics and Electrical Engineering. – Kaunas: Technologija, 2005. – No. 3(59). – P. 46–50.

A plenty of experimental research papers show that in modern computer and telecommunication networks traffic is self-similar. Traditional calculation methods of network switching and processing device parameters are based on the elementary query or packet streams. In a number of researches it is shown, that traditional approach lead to big mistakes in devices parameters definition. These conclusions have been made on the basis of devices stationary operating mode analysis. In the given work devices non-stationary operating mode at near to self-similar query stream influence is considered. Ill. 12, bibl. 4 (in English, summaries in Lithuanian, English, Russian).

С. Илницкис, Е. Петерсонс, Р. Еремінс. Иследование нестационарного поведения сервера // Электроника и электротехника. – Каунас: Технология, 2005. – № 3(59). – С.46–50.

Традиционные исследования соединений в сети и параметров устройств основаны на исследовании элементарных потоках запросов и пакетов. Многие исследования показали, что традиционный подход к этой проблеме влечет за собой большие ошибки оценки параметров устройств. Этот вывод был сделан на основании анализа состояний стационарного функционирования устройств. В статье представлена оценка состояний нестационарного функционирования устройств под влиянием потока запросов. Ил. 12, библ. 4 (на английском языке; рефераты на литовском, английском и русском яз.).