ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2006. Nr. 7(71)
ELEKTRONIKA IR ELEKTROTECHNIKA

T121 SIGNAL TECHNOLOGY
SIGNALŲ TECHNOLOGIJA

Client-Server Model Non-Stationary Behaviour Research at Near Self-Similar Query Stream Influence Under the Condition of Overloaded Terminal System

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1. 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.

2. 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

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

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

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

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

$$\begin{cases} y = \dfrac{x}{\left|a^\circ/b^\circ\right|} = \dfrac{x}{\left|(C1+C2\rho)/(1-\rho)\right|} \\ \tau = \dfrac{t}{\left|a^\circ/b^\circ\right|} = t/\mu_1\,(C1+C2\rho)/(1-\rho)^2 \end{cases}; \qquad (3)$$

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

$$(\partial/\partial\tau)\rho(y_0,y;\tau) = \tfrac{1}{2}(\partial^2/\partial y^2)\rho(y_0,y;\tau) - -\delta\cdot(\partial/\partial y)\rho(y_0,y;\tau) \qquad (4)$$

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

$$\tfrac{1}{2}(\partial\ \ /\partial y\ \ )\rho(y_0,y;\tau) - \delta\cdot\rho(y_0,y;\tau) = 0, \qquad (5)$$

if $y=0$ and $y=b$,

where

$$\delta = \begin{cases} 1, & \rho < 1, \\ 0, & \rho = 1, \\ -1, & \rho > 1, \end{cases} \qquad (6)$$

$$b = (N+1)/\left|(C1+C2\rho)/(1-\rho)\right|. \qquad (7)$$

Applying the method of "eigenfunction expansion", we obtain the following solution for (4):

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

if y>b,

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

$$\Phi_n(y) = \left[2\lambda_n^2\cdot b(\lambda_n^2+1)\right]^{2}\left\{\cos\lambda_n y + (\delta/\lambda_n)\sin\lambda_n y\right\}; \qquad (9)$$

where $\lambda_n = n\pi/b$, $n = 1,2,3,\ldots$.

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.

3. 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. In [5] it was considered a case when a server is overloaded.

Let's consider a case when utilization factor is more than 1. Fig. 1 shows dependence of number of queries in the buffer and Fig. 2 – denial of service probability.

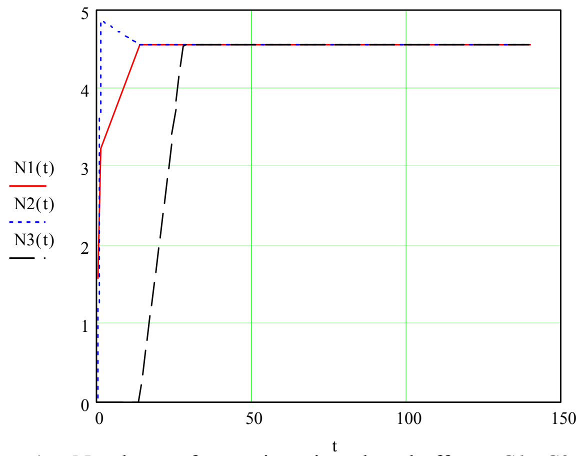

Fig. 1. Number of queries in the buffer, *C1=C2=1,* $\rho = 1{,}1$

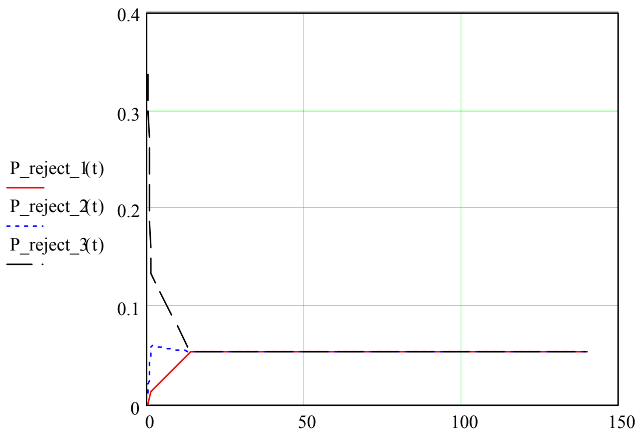

Fig. 2. Denial of service probability, *C1=C2=1,* $\rho = 1{,}1$

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

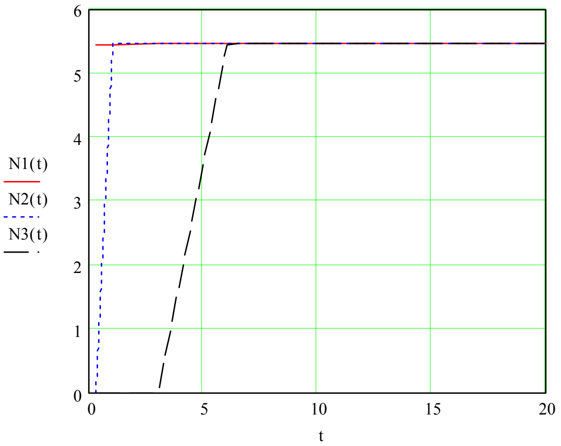

Fig. 3. Number of queries in the buffer, *C1=1, C2=50,* $\rho = 1{,}1$

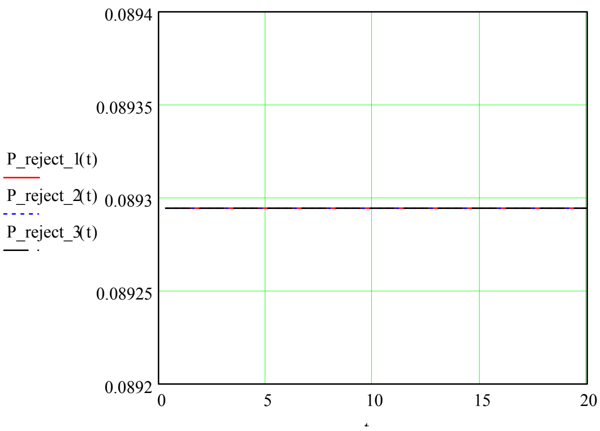

Fig. 4. Denial of service probability, *C1=1, C2=50,* $\rho = 1{,}1$

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 $\rho = 5$.

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.

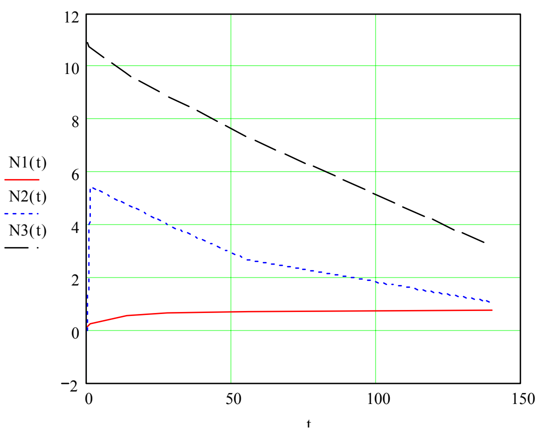

Fig. 5. Number of queries in the buffer, *C1=C2=1,* $\rho = 5$

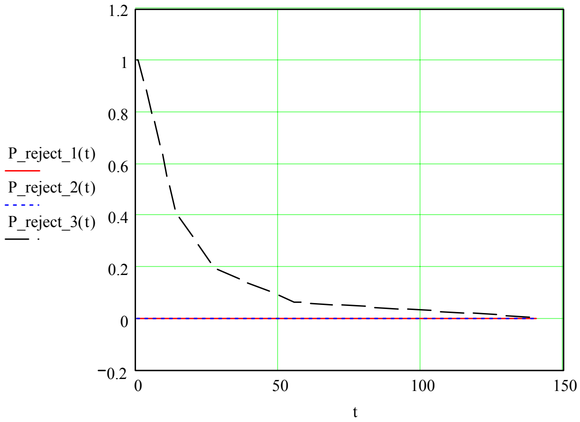

Fig. 6. Denial of service probability, *C1=C2=1,* $\rho = 5$

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.

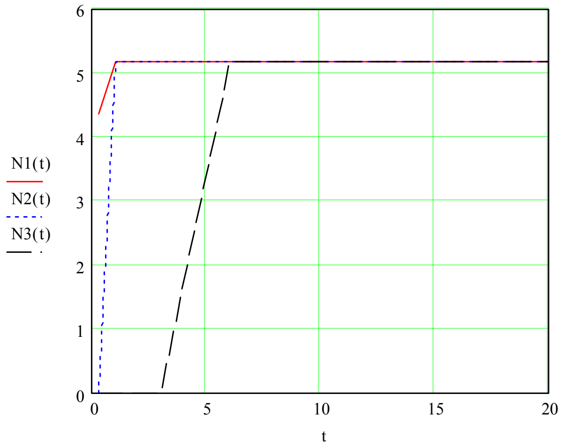

Fig. 7. Number of queries in the buffer, *C1=1, C2=50,* $\rho = 5$

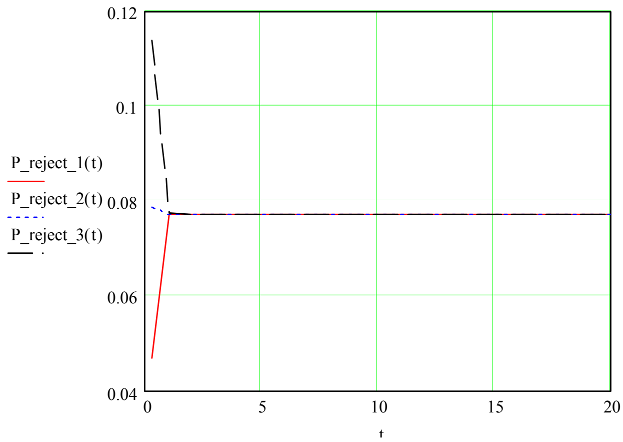

Fig. 8. Denial of service probability, *C1=1, C2=50,* $\rho = 5$

The obtained results allow to make conclusions on character of behaviour of a client-server model 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!

Comparing values of denial of service probability for C2=50 in relation to a stream, described by variation coefficient C2=1 we come to result which shows that in a transitive mode denial of service probability sharply increases while input stream tends to self-similar. The average number of queries in buffer memory also increases while C2 increases.

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.

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 client-server model – 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 client-server model work differs from the values in case of elementary query input stream.

References

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3. **Kihong Park, Walter Willinger.** Self-Similar Network Traffic and Performance Evaluation. John Wiley & Sons, INC. – 2000. – P. 558.
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5. **Ilnickis S., Petersons E., Jerjomins R.** Server non-Stationary Behaviour Research at Near to Self-Similar Query Stream Influence. – Kaunas, 2005.

Submitted for publication 2006 05 10

R. Jerjomins, E. Petersons. Client-Server Model Non-Stationary Behaviour Research at Near Self-Similar Query Stream Influence Under the Condition of Overloaded Terminal System // Electronics and Electrical Engineering. – Kaunas: Technologija, 2006. – No. 7(71). – P. 35–38.

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 terminal-server system non-stationary operating mode at near to self-similar query stream influence is considered. Ill. 8, bibl. 5 (in English, summaries in English, Russian, Lithuanian).

Р. Ерьеминс, Э. Петерсонс. Исследование нестационарного поведения модели клиент–сервер при наличии запросов в условиях системы перегруженного терминала // Электроника и электротехника. – Каунас: Технология, 2006. –№ 7(71). – С. 35–38.

Многие работы с экспериментальными исследованиями показали, что в современных компьютерных и телекоммуникационных сетях потоки данных похожие. Традиционные методы коммутирования сети и обработки данных основаны на элементарных запросах или допущения потоков пакетов. Разные исследования показали, что традиционный подход способствует большим ошибкам при установлении параметров приборов. Такие заключения были сделаны на основе анализа режима работы прибора. Рассмотрен режим нестационарной работы системы терминал-сервер при действии потока похожих запросов. Ил. 8, библ. 5 (на английском языке; рефераты на английском, русском и литовском яз.).

R. Jerjomins, E. Petersons. Kliento ir serverio modelio nestacionarios elgsenos tyrimas, esant panašių užklausų srautui ir perkrautai terminalo sistemai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2006. – Nr. 7(71). – P. 35–38.

Dauguma eksperimentinių tyrimų rodo, kad šiuolaikiniuose kompiuterių ir telekomunikacijų tinkluose duomenų srautai yra panašaus pobūdžio. Tradiciniai tinklo komutavimo ir duomenų apdorojimo įtaisų parametrų skaičiavimo metodai remiasi elementariųjų užklausų arba paketų srautų prielaida. Įvairūs tyrimai rodo, kad šiais metodais nustatant įtaisų parametrus padaroma didelių klaidų. Tokios išvados buvo padarytos remiantis įtaisų stacionaraus darbo režimo analizės duomenimis. Šiame darbe nagrinėjamas terminalo ir serverio sistemos nestacionaraus darbo režimas, veikiant panašių užklausų srautui. Il. 8, bibl. 5 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).