Modeling of Self-similar Traffic

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***Abstract*—Modeling of self-similar traffic is performed for the queuing system of G/M/1/K type using Weibull distribution. To study the self-similar traffic the simulation model is developed by using SIMULINK software package in MATLAB environment. Approximation of self-similar traffic on the basis of spline functions. Modeling self-similar traffic is carried out for QS of W/M/1/K type using the Weibull distribution. Initial data are: the value of Hurst parameter *H*=0,65, the shape parameter of the distribution curve $\alpha \approx 0{,}7$ and distribution parameter $\beta \approx 0{,}0099$. Considering that the self-similar traffic is characterized by the presence of "splashes" and long-term dependence between the moments of requests arrival in this study under given initial data it is reasonable to use linear interpolation splines.**

***Keywords*: self-similar traffic, Hurst parameter, Weibull distribution, modeling, queuing system, approximation, spline function.**

I. INTRODUCTION

Modern telecommunications networks are developing now in the direction of the next generation networks NGN (Next Generation Network), that are based on the application of package technologies to transmit different types of traffic on a single network infrastructure providing quality characteristics QoS (Quality of Service) [1][2].

By its nature, the traffic, serviced in NGN network, is heterogeneous, as it is formed by many but different in their characteristics sources of services and network applications, ensuring the provision of services for voice, data and video TPS (Triple Play Service) [1][2].

It is known [3] that the packet traffic has train character and has the property of self-similarity, the cause of which is a long-term dependence between the moments of package arrival determined by the correlation function at different points in time.

The flow of self-similar traffic is also characterized by the presence of aftereffect, i.e. if the number of requests received by the queuing system after the moment t depends on the number of requests received before the time t [3].

To describe self-similar traffic, considering that the moments of packages arrival have the distribution with "heavy-tailed", often use the distribution of Pareto, lognormal or Weibull [3].

The degree of self-similar traffic is estimated by Hurst parameter. Besides, the self-similarity traffic has the structure being saved in multiple scaling. But real traffic, as a rule, has the number of more “splashes”. It dramatically worsens the value of quality characteristics QoS (values of loss probability, package delay time and jitter) [3].

Taking into account the above said, modeling of the traffic will allow to avoid network overload, exceedance of the standard values of delay time and jitter, considering peakedness of package traffic.

Today, the problem of characteristics evaluation of self-similar traffic characteristics is devoted a considerable amount of works of different authors [5]-[7].

Most of the works are based on experimental data and obtained results of simulation modeling using the R/S analysis, Whittle evaluation, wavelet analysis, and many other methods [5][6].

One of the instruments for investigating the characteristics of self-similar traffic is a simulation modeling that allows obtaining the necessary characteristics. And the choice of the form of approximation of received results is a hot topic of virtually any research [5]-[7].

The application of linear spline to approximate the self-similar traffic is offered in this work.

The aim of this work is to study the characteristics of self-similar traffic using the worked out simulation model in SIMULINK package of MATLAB environment with the following approximation by linear splines.

II. MODELING OF SELF-SIMILAR TRAFFIC USING THE SIMULINK PACKAGE IN MATLAB ENVIRONMENT

Let we perform modeling of self-similar traffic for queuing system (QS) of G/M/1/K type that serves the requests stream, which intervals are described by arbitrary distribution G, the time of service has exponential distribution M, QS has 1 line and length of requests queue is K [3-4].

In this case, for modeling the process of service requests arrival we use QS of W/M/1/K type, where

W − is a stream of requests with Weibull distribution,

M − is time of requests service distributed according to an exponential law, QS − has 1 line and length of requests queue is K [3-4].

Let we consider the Weibull distribution, given by the differential distribution function [3-4]:

$$f(x)=\begin{cases}\alpha\beta x^{\alpha-1}e^{-\beta x^{\alpha}}, & x\ge 0,\\ 0, & x\le 0\end{cases} \qquad (1)$$

where α – is a parameter of distribution curve form ($0<\alpha<1$); $\alpha=2-2H$,

H – Hurst parameter, ($0{,}5\le H\le 1$),

$\beta=\left[\lambda\Gamma\left(1+\frac{1}{\alpha}\right)\right]^{-1}$ – distribution parameter, $\beta>0$,

Γ – gamma function,

λ – intensity of requests arrivals for QS servicing.

The integral function of Weibull distribution has the following form [3]:

ack/s,

μ – request servicing durability, μ= 125 s,

K – the length of requests queue, K=100 requests.

For modeling of self-similar traffic let we set the value of Hurst parameter H=0,65.

Then for distribution of Weibull parameters α and β are equal respectively $\alpha\approx0{,}7$ and $\beta\approx0{,}0099$.

$$F(x)=1-e^{-\beta x^{\alpha}}. \qquad (2)$$

Generation of a random value of time interval between requests arrivals in self-similar stream formation in the simulation model is performed by the transition from uniform distribution by the inverse function method according to the expression [3]:

$$x=\beta\left[-Ln(1-R)\right]^{\frac{1}{\alpha}}, \qquad (3)$$

where $R\in[0;1]$ – is uniform distributed random number.

As the initial data of QS W/M/1/K operation, we use its following characteristics:

λ – intensity of requests arrivals for servicing in QS, λ =100

The received results of modeling self-similar traffic for QS of W/M/1/K type for the given initial data using SIMULINK package of MATLAB environment is shown in Fig. 1, where

N – the number of requests,

t – requests arrival time.

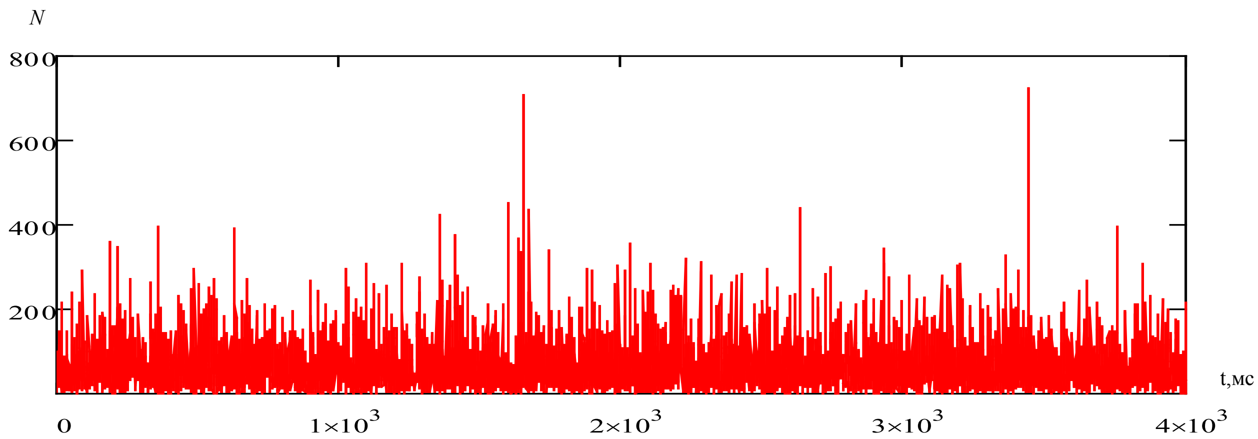

Fig.1. Simulation of self-similar traffic for QS of W/M/1/K type.

According to the received modeling results shown in Fig. 1, we can conclude the following.

The resulting graph shows that the process is no uniform and corresponds to the above described characteristics of self-similarity.

There is scale invariance, the presence of "splashes" of requests and long-term dependence between the moments of request arrivals.

III. Approximation of Self-Similar Traffic by Spline Functions

Simulation of self-similar traffic performed for the QS of W/M/1/K type.

To approximate self-similar traffic we use spline functions, which allow effectively solving the problems of processing various statistics data and experimental dependences having rather complex structure [5].

In this work, we consider the use of linear interpolation splines [8-10].

Let we consider using linear interpolation spline to approximate the results of traffic modeling obtained for the QS of W/M/1/K type, using the SIMULINK package of MATLAB environment, which are shown in Fig. 1.

To approximate by the linear spline the self-similar traffic, shown in Fig. 1, let we perform the selection of values, for example, on the time interval $[3813;3990]$, which is a series of long-term dependency. Fig. 2 shows a selection for a predetermined of time interval.

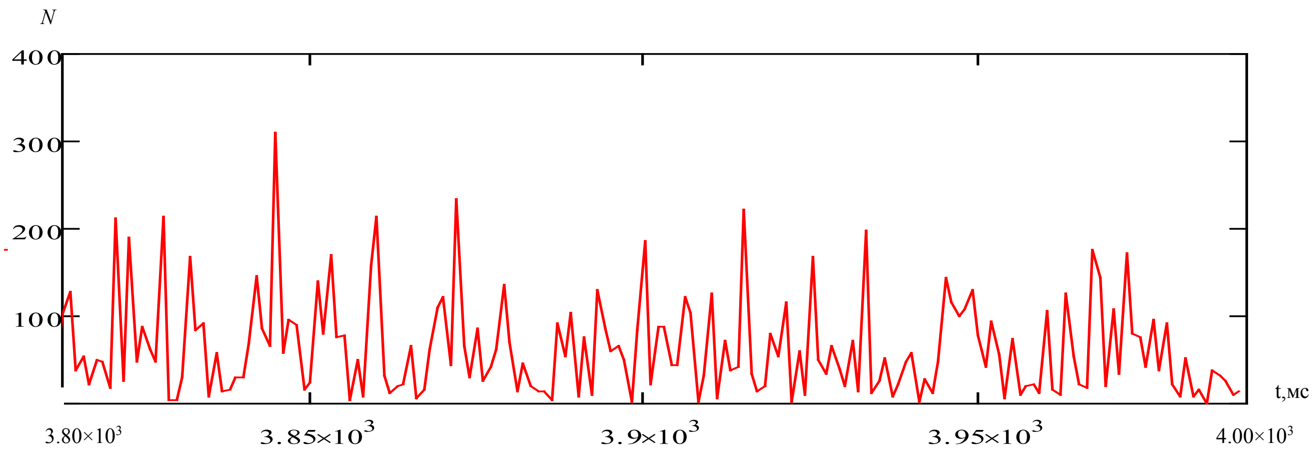

Fig.2. Selection of values for self similar traffic for the interval of values $[3813;3990]$.

Let on the interval $[0;T]$ the values results of traffic modeling are set.

Let we divide this interval $[0;T]$ by points Δ:

$$0 = t_0 < t_1 < \ldots < t_N = T$$

on the interval $[t_i;t_{i+1}]$, $i = \overline{0, N-1}$ on each let we build polynomial of certain degree.

Such polynomial we will use linear spline [7-10].

According to [8-10], interpolation linear spline $S_1(t_i)$ on the interval $[t_i;t_{i+1}]$, $i = \overline{0, N-1}$ – is the continuous piecewise linear function.

Let in the nodes of Δ grid be set values

$$s_i = s(t_i), \quad i = \overline{0, N}$$

some functions $s(t)$, defined on the interval $[t_i;t_{i+1}]$.

Interpolation spline $S_1(t_i)$ is defined by the conditions [8-10]:

$$S_1(t_i) = S_i, \; i = \overline{0, N}. \tag{4}$$

If we define $h_i = t_{i+1} - t_i$, so with $t \in [t_i, t_{i+1}]$ the equation of linear spline will be [6]:

$$S_1(t) = f_i \frac{t_{i+1} - t}{h_i} + f_{i+1} \frac{t - t_1}{h_i}, \tag{5}$$

or

$$S_1(t) = f_i + \frac{t - t_1}{h_i}(f_{i+1} - f_i). \tag{6}$$

Let we consider the self-similar traffic on the selected interval $[3813;3990]$ by setting a uniform grid of decomposition with intervals h=0,01.

For each point of decomposition the values of requests numbers are known in each interpolation node.

Using linear interpolation spline $S_1(t_i)$ and expressions (4-6), we get an approximation of the traffic, shown in Fig. 3.

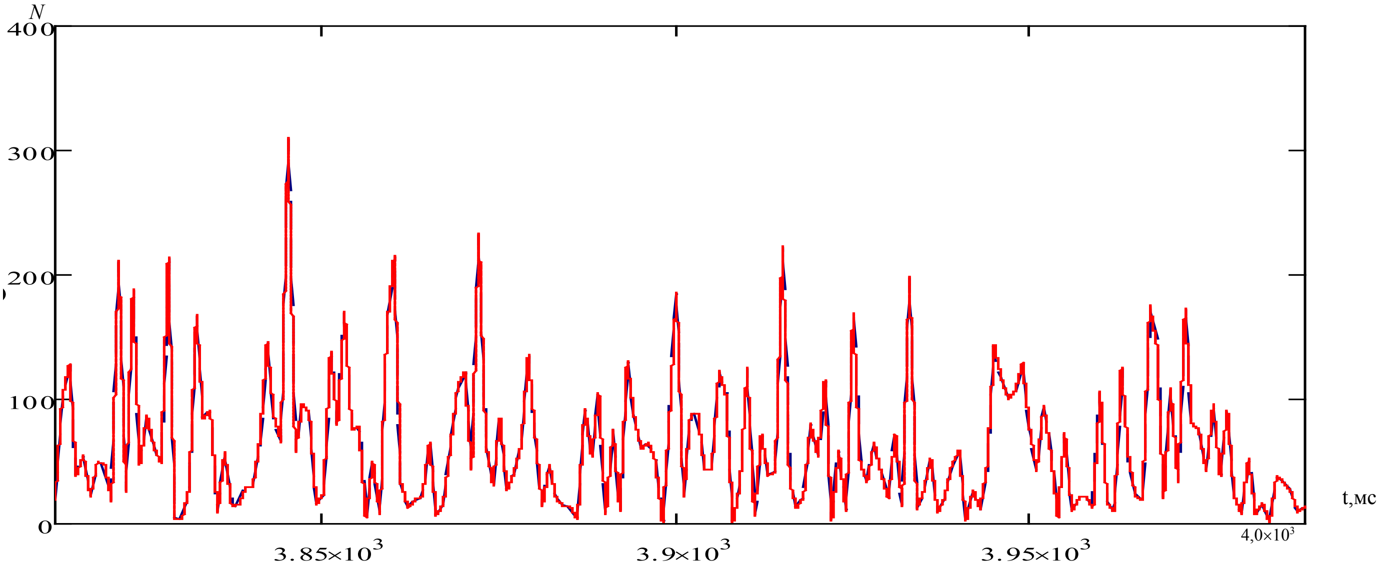

Fig.3. Approximation of self similar traffic by linear spline

The received results suggest the possibility of using linear interpolation splines for approximation of self-similar traffic obtained by the worked out simulation model by using SIMULINK package in MATLAB environment.

IV. Conclusions

1. Modeling of self-similar traffic for QS of W/M/1/K type:

– incoming stream of requests distributed under the law of Weibull,

– distribution of service time – exponential,

– single-line system,

– the length of the queue of requests is K is performed.

2. With the help of SIMULINK software package in MATLAB environment the simulation model is developed to study the characteristics of self-similar traffic.

3. Modeling self-similar traffic is carried out for QS of W/M/1/K type using the Weibull distribution. Initial data are:

– the value of Hurst parameter H=0,65,

– the shape parameter of the distribution curve $\alpha \approx$0,7 and distribution parameter $\beta \approx$0,0099.

4. Approximation of self-similar traffic by linear splines is considered.

5. Considering that the self-similar traffic is characterized by the presence of "splashes" and long-term dependence between the moments of requests arrival in this study under given initial data it is reasonable to use linear interpolation splines.

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