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Traffic simulation in a telecommunication system based on queuing systems with different input flows

Y. Bobalo[1], R. Politanskyi[1], M. Klymash[2]

[1]Department of Theoretical Radio Engineering and Radio Measurement
[2]Department of Telecommunications,
Lviv Polytechnic National University;
79013, Lviv, Bandery st. 12
E-mail:polrusl@i.ua

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Abstract. The simulation method of queuing system for traffic simulation in telecommunication system is studied. Different types of input flow are considered: uniform distributed, Poisson distributed and self-similar flow with different Herst indexes.
Key words: Herst index, self-similar flow, queuing system, Poisson flow.

INTRODUCTION

When simulating a telecommunication system analytical methods [9] of queuing systems theory (QS), time-probability graphs, differential and difference equations and colored Petri nets are widely used [1, 2, 11, 18, 19, 21, 22]. These methods enable the analytical solutions of rather complex systems [17], but provided that the input flow of QS is described by the probability model with uniform or Poisson distributions [16].

At the same time numerous scientific researches devoted to the description of experimentally found timing diagrams of the traffic intensity, particularly in the Internet, go that the input process is more complicated. Thus, for traffic simulation in telecommunication system it is better to choose the simulation method of QS, which as opposed to analytical methods of QS simulation (suitable for flows with uniform distribution) has an important feature that is the ability to select any probability model of the input flow [8].

MATERIALS AND METHODS

Having analyzed the scientific researches, we concluded that it is necessary to simulate traffic of a telecommunication system with different types of input flows [8, 9].

Topology of a telecommunication network which uses multipath routing of the Internet traffic and for which the simulation was conducted is shown in **Fig. 1**.

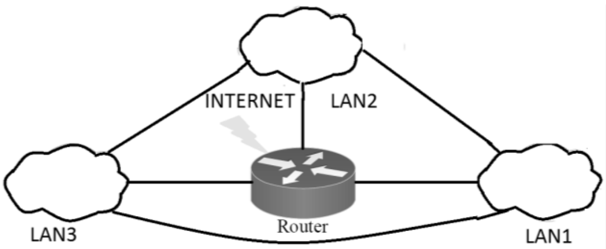

Fig. 1. Mesh network topology with multipath routing

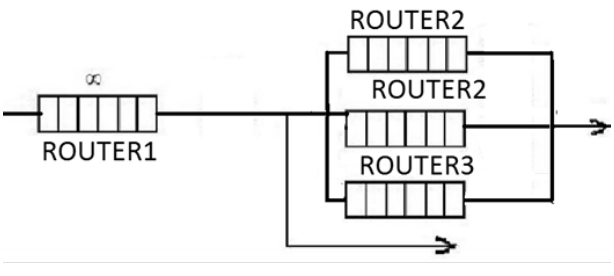

Fig. 2. Multichannel network model with routing and buffering of requests

Traffic simulation was conducted for flows with uniform and Poisson distributions and also for self-similar flows with different self-similarity coefficients.

Poisson flow (**Fig. 3**) is a random process, characterized by the probability of the number of requests [16]:

$$p(N,\tau)=\frac{(\lambda\cdot\tau)^{N}\cdot e^{-\lambda\cdot\tau}}{N!}\,. \qquad (1)$$

where: N – the number of requests, τ – the time of incoming requests, $p(N,\tau)$ – the probability of N requests incoming over time τ, λ – the intensity of flow.

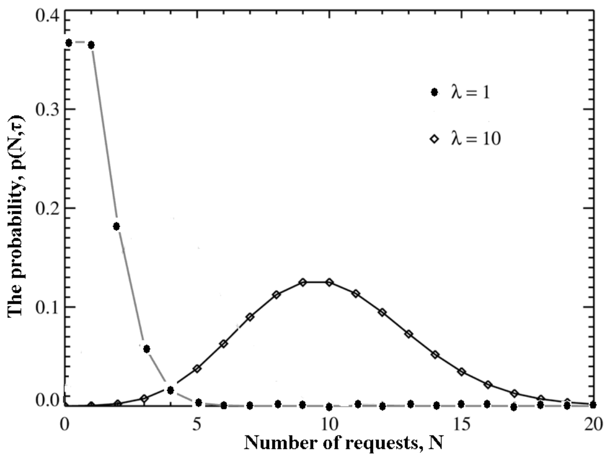

Fig. 3. Poisson distribution for different values of intensity

For self-similar flows generation the model of fractal Brownian signal (FBS) was used that is described by the following formula [10, 11, 20]:

$$X^{(H)}(i)\approx\frac{1}{\Gamma\left(H+\frac{1}{2}\right)}\cdot\left\{\sum_{j=0}^{[n\cdot(i+1)-1]}\left[(i+1)-\frac{j}{n}\right]^{H-1/2}\cdot\right.$$

$$\left.\cdot\xi(j)-\sum_{j=0}^{i\cdot n-1}\left(i-\frac{j}{n}\right)^{H-1/2}\cdot\xi(j)\right\}, \qquad (2)$$

where: H – the Hurst parameter, n – the time scaling parameter of the self-similar signal (minimal value of this parameter is equal to 1), $X^{(H)}(i)$ – the value of FBS sample with number "i", $\xi(i)$ – the number from the set with normal distribution which has zero mathematical expectation and dispersion equals to one.

Generation of real numbers $\xi(i)$ with normal distribution with through Box-Miller algorithm is based on using of two different linear congruent generators:

$$x_{1,n+1}=(a_1\cdot x_{1,n}+d_1)\bmod N\,, \qquad (3)$$

$$x_{2,n+1}=(a_2\cdot x_{2,n}+d_2)\bmod N\,, \qquad (4)$$

where: n – index of current iteration, $x_{1,n}$, $x_{2,n}$, $x_{1,n+1}$, $x_{2,n+1}$ – numbers obtained by the first and second congruent generators in the current and previous iterations respectively, a_1, d_1, N and a_2, d_2, N – parameters of the first and second congruent generators respectively, which should be mutually prime and rather big numbers.

The sequences of real numbers generated by Eq. (3) and Eq. (4) are transformed according to the following transforming [23]:

$$\nu=x_{1,n}^2+x_{2,n}^2\,, \qquad (5)$$

$$y_{1,n}=x_{1,n}\cdot\sqrt{\frac{-2\cdot\log(\nu)}{\nu}}\,, \qquad (6)$$

$$y_{2,n}=x_{2,n}\cdot\sqrt{\frac{-2\cdot\log(\nu)}{\nu}}\,, \qquad (7)$$

where: $x_{1,n}$, $x_{2,n}$ – uniformly distributed pseudorandom numbers, $y_{1,n}$, $y_{2,n}$ – pseudorandom numbers with Gaussian distribution.

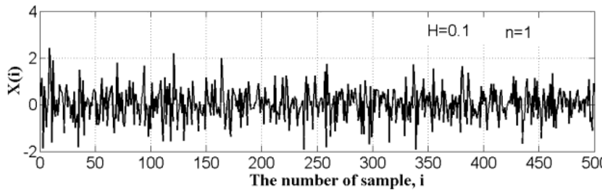

Fig. 4a. Timing diagrams of FBS with different Hesrt indexies and the time scaling factors: (H=0,1; n=1), (H=0,1; n=50), (H=0,9; n=1), (H=0,9; n=50) – a), b), c) and d) respectively

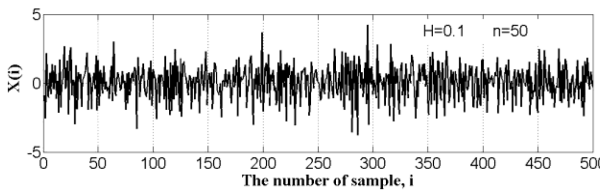

Fig. 4b. Timing diagrams of FBS with different Hesrt indexies and the time scaling factors: (H=0,1; n=1), (H=0,1; n=50), (H=0,9; n=1), (H=0,9; n=50) – a), b), c) and d) respectively

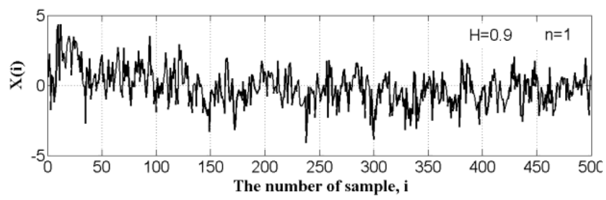

Fig. 4c. Timing diagrams of FBS with different Hesrt indexies and the time scaling factors: (H=0,1; n=1), (H=0,1; n=50), (H=0,9; n=1), (H=0,9; n=50) – a), b), c) and d) respectively

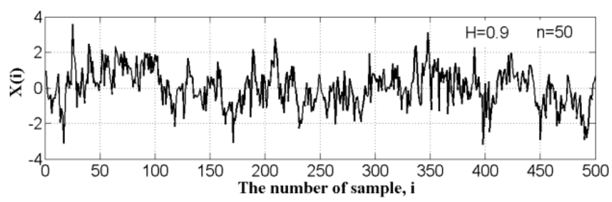

Fig. 4d. Timing diagrams of FBS with different Hesrt indexies and the time scaling factors: (H=0,1; n=1), (H=0,1; n=50), (H=0,9; n=1), (H=0,9; n=50) – a), b), c) and d) respectively

If the sum of the squares of numbers $x_{1,n}$ and $x_{2,n}$ in Eq. (5) is greater than one, the calculation by Eq. (6) and Eq. (7) are not performed, and thus starts the next iteration.

Time diagram of FBS generated according to Eq. (2) indicates their chaotic behaviors (Fig. 4) [3, 4, 13, 14, 15].

The essence of the proposed traffic simulation method with self-similar distribution is the following:

– from generated values in accordance with Eq. (2) we subtract the minimal value of the same numerical series that makes it possible to obtain the graph with nonnegative values;

– we multiply terms of created numerical series by the same coefficient, the value of which we select provided that obtained numerical series had equal intensity values;

– we round obtained values to the integer number, as they represent the number of requests which come to the network over one time interval that is similar for all types of traffic;

– thus, we obtained the specified flow intensity, which is simulated by integer numbers during each time iteration;

– time spaces between transmission of requests to systems over one time iteration are estimated inversely proportional to the number of req. over one iteration.

RESULTS AND DISCUSSION

The first result obtained in our research was calculation of the requests mean service time in the network depending on the network load. The calculation was done for different flow intensities. We determined that for intensity value $0{,}9\cdot10^5$ requests/hour balancing of the process of req. transmission is observed: so mean time does not depend on the number of req.

We also found out that the traffic with different types of distribution would be transmitted differently through the network (**Fig. 5**).

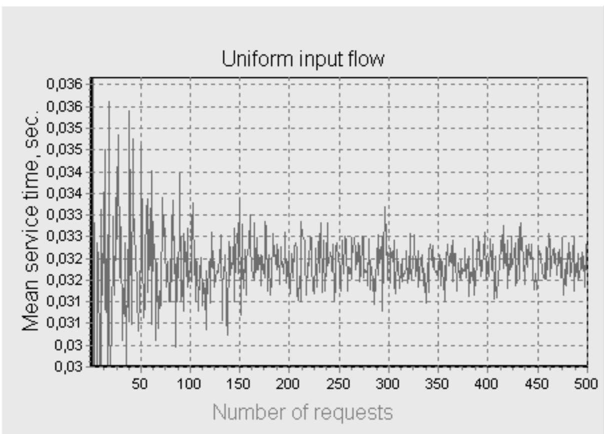

Fig. 5a. The dependence of traffic transmission time on the input flow intensity that is equal to $0{,}9\cdot10^5$ requests/hour with different distributions – uniform, Poisson and self-similar when H=0,3: a), b) and c) respectively

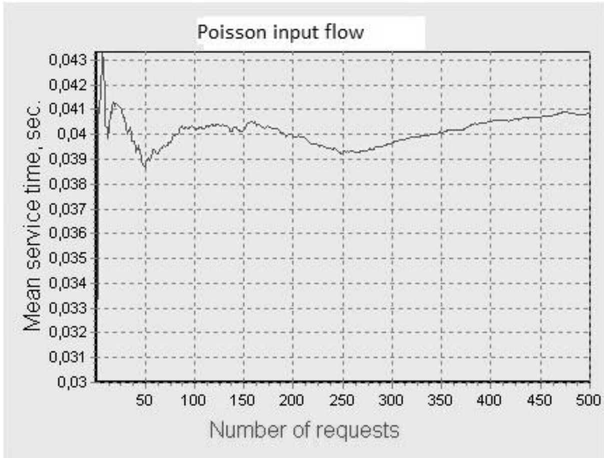

Fig. 5b. The dependence of traffic transmission time on the input flow intensity that is equal to $0{,}9\cdot10^5$ requests/hour with different distributions – uniform, Poisson and self-similar when H=0,3: a), b) and c) respectively

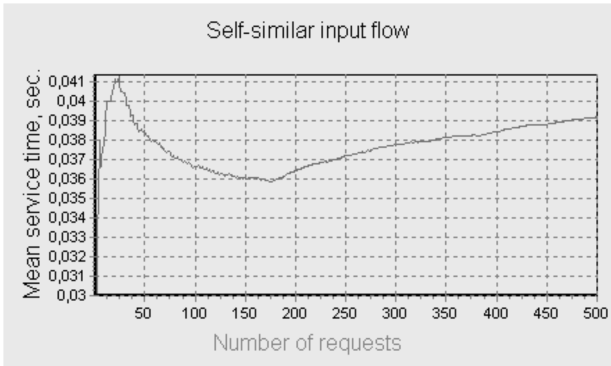

Fig. 5c. The dependence of traffic transmission time on the input flow intensity that is equal to $0{,}9\cdot10^5$ requests/hour with different distributions – uniform, Poisson and self-similar when H=0,3: a), b) and c) respectively

Herewith, maximum value of the requests mean service time is for Poisson traffic (**Fig. 5**). The calculated average value of the req. mean service time in the network for flows with different distribution is shown in **Table 1**.

Table 1. Requests mean service time in the network.

Type of traffic	Req. mean service time in the network, sec.
Uniform	0,033
Poisson	0,041
Self-similar	0,039

We also determined some relation of self-similar traffic transmission for different Hurst exponents (**Fig. 6**). From the obtained results of the research of the dependence of self-similar traffic transmission time for different Hurst exponents it follows that minimum average value of self-similar traffic transmission occurs provided that the number of requests is equal to 270, 120…270, and 270 for H=0.1; 0,5 and 0,9 respectively.

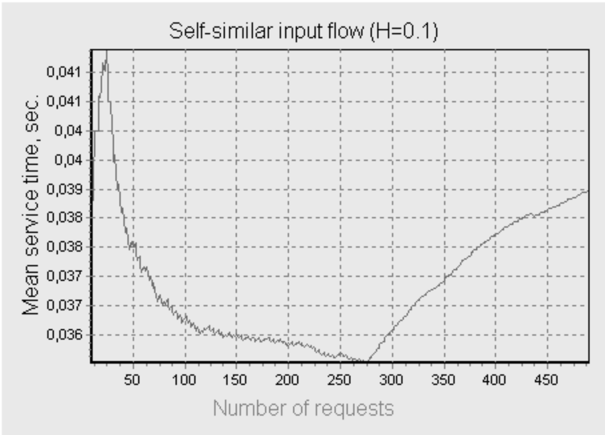

Fig. 6a. The dependence of characteristics of the output flow when flow intensity equals to $0{,}9\cdot10^5$ requests/hour for self-similar input traffic with Hurst exponents 0,1; 0,5, 0,9: a) b) and c) respectively

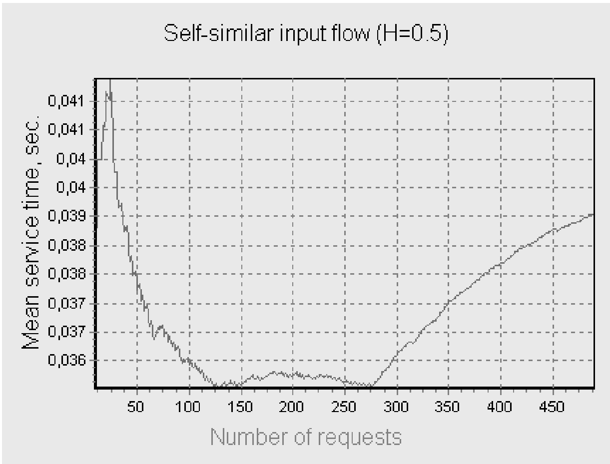

Fig. 6b. The dependence of characteristics of the output flow when flow intensity equals to $0{,}9\cdot10^5$ requests/hour for self-similar input traffic with Hurst exponents 0,1; 0,5, 0,9: a) b) and c) respectively

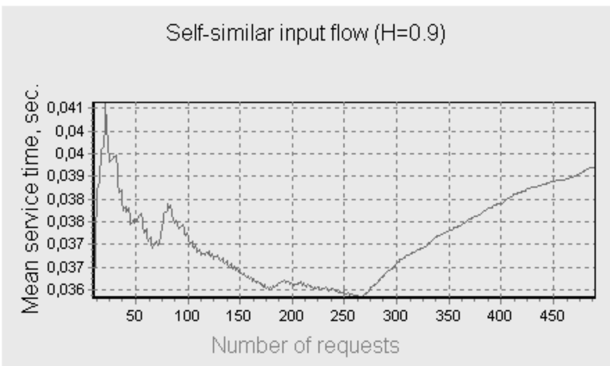

Fig. 6c. The dependence of characteristics of the output flow when flow intensity equals to $0{,}9\cdot10^5$ requests/hour for self-similar input traffic with Hurst exponents 0,1; 0,5, 0,9: a) b) and c) respectively

If we decrease the input traffic intensity to $1{,}8\cdot10^3$ the characteristics of transmission through the network of flows with Poisson and self-similar distributions are identical and they differs from the characteristic for uniform distribution. We can make such conclusion on the basis of data shown in **Fig. 7**.

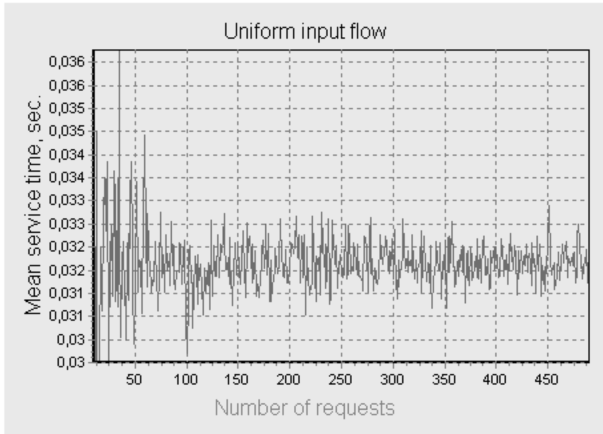

Fig. 7a. Requests mean service time in the network for uniform, Poisson and self-similar traffics when the intensity of the input flow is equal to $1{,}8\cdot10^3$ req./hour: a) and b) respectively

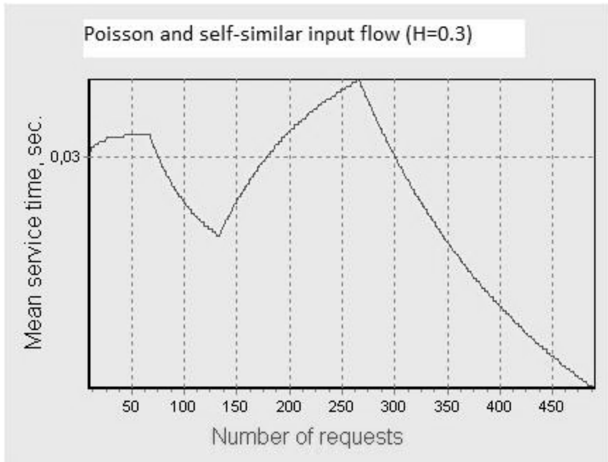

Fig. 7b. Requests mean service time in the network for uniform, Poisson and self-similar traffics when the intensity of the input flow is equal to $1{,}8\cdot10^3$ req./hour: a) and b) respectively

CONCLUSIONS

1. On the basis of the conducted simulation we determined that there are some divergences between traffics simulated by different flows. In particular, the results obtained for the flow with uniform distribution differ from the results obtained when simulating the traffic by the self-similar and Poisson flows. Herewith, flows with self-similar and Poisson distributions are identical when the intensity is equal to $1{,}8\cdot10^3$ req./hour.

2. If the intensity is increased to $0{,}9\cdot10^5$ req./hour the difference in calculating of such average transmission time of one req. for flows with self-similar and uniform distributions is equal to $8\cdot10^{-3}$ seconds,

and for flows with self-similar and Poisson distributions the difference is equal to $2,0 \cdot 10^{-3}$ seconds. In our opinion this is the substantial divergence for the Poisson and self-similar flows.

3. We also determined that there is no the substantial dependence of the mean service time on the self-similarity coefficient (Hurst exponent) of the flow, but processes of transmission self-similar flows with different Hurst exponent are differ from each other considerably.

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