A Model of Video Traffic Transmission in IP Networks

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Abstract — Telecommunications and network technology is now the driving force that ensures continued progress of world civilization. Design of new and expansion of existing network infrastructures requires improving the quality of service (QoS). Modeling probabilistic and time characteristics of telecommunication systems is an integral part of modern algorithms of administration of quality of service. At present, for the assessment of quality parameters except simulation models analytical models in the form of systems and queuing networks are widely used. Because of the limited mathematical tools of models of these classes the corresponding parameter estimation of parameters of quality of service are inadequate by definition. Especially concerning the models of telecommunication systems with packet transmission of multimedia real-time traffic.

***Keywords:** telecommunication systems; TCP/IP; mathematical simulation; queuing system*

I. INTRODUCTION

For the transmission of multimedia information in real-time IP technology is widely used. It is known that IP does not provide data transfer with guaranteed parameters of quality of service, however, modern communication services, such as Video on Demand (VoD), place high demands on parameters such as the one-way delay and jitter.

In connection with the abovementioned, the task of the evaluation, and control of parameters of quality of transmission of multimedia data under real load conditions is actual. To solve this, it is necessary to develop the complex of mathematical models that provide assessment of major parameters of quality: one-way delay, the probability of delivery, jitter. This problem is the subject of a number of works of Russian and foreign researchers. So, for example in [1] the impact of the IP network on the quality of the video transmission stream is tested.

Mathematical modeling is one of the main research methods of telecommunications systems. The mathematical model should provide: adequate mapping of various network processes, assessment with the required accuracy the parameters of these processes and the interpretation of modeling results and effective use of computing resources, the use of the model in real time. The class of mathematical models includes discrete or continuous dynamical systems, Markov processes, systems and queuing networks, graphs, hyper graphs, hyper-networks, Petri nets, statistical models, etc.

To evaluate the performance of video transmission traffic in a packet-switched networks often the method of queuing theory and Markov models [2, 3] is used. In [4], the results of performance simulation of the MAC protocol TDMA in wireless networks for a variety of multimedia applications are discussed. Publications in [5-11] are devoted to the application of Markov processes and queuing systems for the analysis of the transmission of multimedia traffic in networks with different architectures (GSM, CDMA, ATM, etc.).

The models based on the use of the apparatus of inhomogeneous closed queuing networks have showed their effectiveness in solving the problem of estimation of parameters of the quality of service in communication systems. Good properties of the method are result of to the fact that the processes of statistical multiplexing most adequately described by the process of queuing, and all possible combinations of the transmitted traffics delays are well described by the topology of these networks, as well as the development of the theory queuing networks and of effective computational methods for calculating them.

II. DESCRIPTION OF THE TELECOMMUNICATIONS SYSTEM

A simulative modeling was carried out for the system shown in Figure 1. Here you can see a telecommunications system, which provides the clients with real-time information service – e.g. video on demand (VoD).

A typical communications system that provides this service consists of the following components:

- a video server connected to the switch IP network through a Gigabit Ethernet link;
-a client workstation, which is interconnected with its own switch to a Fast Ethernet link;
- multiple switches provide transfer of traffic from the server to the subscriber and back.

Video stream that is transmitted to the client workstation is encoded in MPEG-4 [12]. For transmission at the transport layer protocols RTCP and TCP are used, on a network - protocol IPv4.

In this model traffic going to the switch from/to other clients, is a background load, which can significantly affect the delay and jitter.

For the mathematical description of the system (Figure 1) it is necessary to specify three classes of parameters:

- parameters of information load;
- parameters of telecommunications equipment;
- software settings.

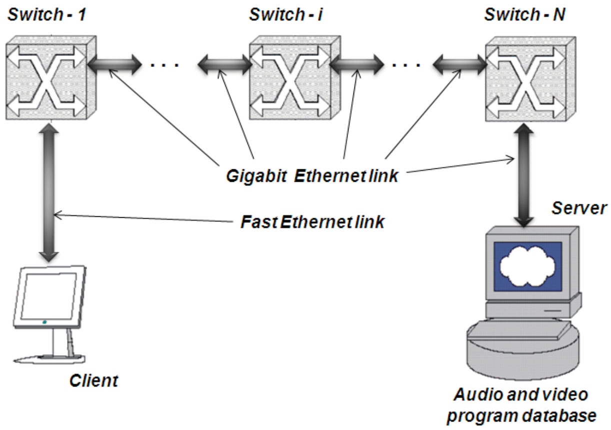


Figure 1. The structure of IP networks for video traffic

III. DESCRIPTION OF THE ANALYTICAL MODEL

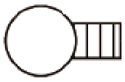
For the evaluation of quality parameters of the transmission of multimedia data, including jitter of one-way delay video stream, an analytical model was developed in the class of inhomogeneous of closed queuing networks. In the proposed network model of service, its classes of requirements display the corresponding information flows that occur in the transmission media stream. The nodes of this model display elementary delays that undergone by the elements of these flows in the various components of the telecommunication network, when passing the route of delivery.

The proposed queuing networks (Figure 2) take into account the composition and the topology of the telecommunication network, technology used, as well as the parameters of information load, defined by the information service video on demand. Network service model consists of L nodes and K classes of requirements, the number of which is determined by the structure of the traffic by the size of different types of frames, by the number of intermediate switches, by the parameters of communication lines, as well as by the background load on the transport subsystem.

The developed model takes into account hardware, software, and information parameters of the simulated system. It allows us to estimate one-way delay jitter, as well as obtain a wide set of probabilistic-time characteristics, namely: the coefficient of utilization of various types of equipment; the delay in the transmission of video frames of each type; on the average number of IP packages for different purposes in each communication site, network bandwidth, etc.

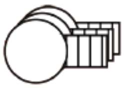
A. *The components of the network model of service*

Nodes of network model of service are used to display various types of transmission delays and processing elements of the information flows in telecommunications equipment of modeled of system. In Figure. 2 to display the nodes of network of service, different types of services in use, the following notations are used:



- Used to refer to the node of network of service, which is the queuing system, type G / G / 1 / ∞, which uses a service discipline FCFS (First Come First Served, service requirements in order of arrival);

- Used to refer to the node of network of service, which is the queuing system of type G / G / ∞ / ∞, which uses a service discipline IS (Infinity Server, service requirements with an infinite number of devices);



- Is used to describe a group of similar hosts service are queuing type G / G / 1 / ∞, which use the service discipline FCFS.

B. *Description node network model*

The network nodes represent the service:

P_p - The time interval between successive P_{xp}-frames, $x_p \in S_P$, $p = \overline{1, L_P}$;

B_b - The time interval between successive B_{xb}-frames, $x_b \in S_B$, $b = \overline{1, L_B}$;

V_v - The time interval between successive V_{xv}-packets of audio accompaniments, $x_v \in S_V$, $v = \overline{1, L_V}$;

D^{Sv} - Delays of sending video server TCP-segments, in which encapsulated RTP-frames with video frames or sound packets;

D_i^{Sw} - Delays of IP-packets switching in the Sw_i-switch; $i = \overline{1, N}$;

D^{Ws} - Delays of IP-packets processing that contain footage taken by RTP in by the Working Station Ws;

D_i^{dw} - Delays in the transmission of Ln_i^G Gigabit Ethernet MAC frames with link-governmental encapsulated IP packets transmitted workstation Ws, $i = \overline{1, N}$;

D_i^{up} - Delays in the transmission of Ln_i^G Gigabit Ethernet MAC frames with link-governmental encapsulated IP packets transmitted to the video server Sw, $i = \overline{1, N}$;

D_i^{pr} - Delays of signal propagation of Ln_i^G Gigabit Ethernet link, $i = \overline{1, N}$;

D^{dw} - Delays of MAC-frames transmission with encapsulated IP packets destined for video server to the workstation in Ln^F the Fast Ethernet link;

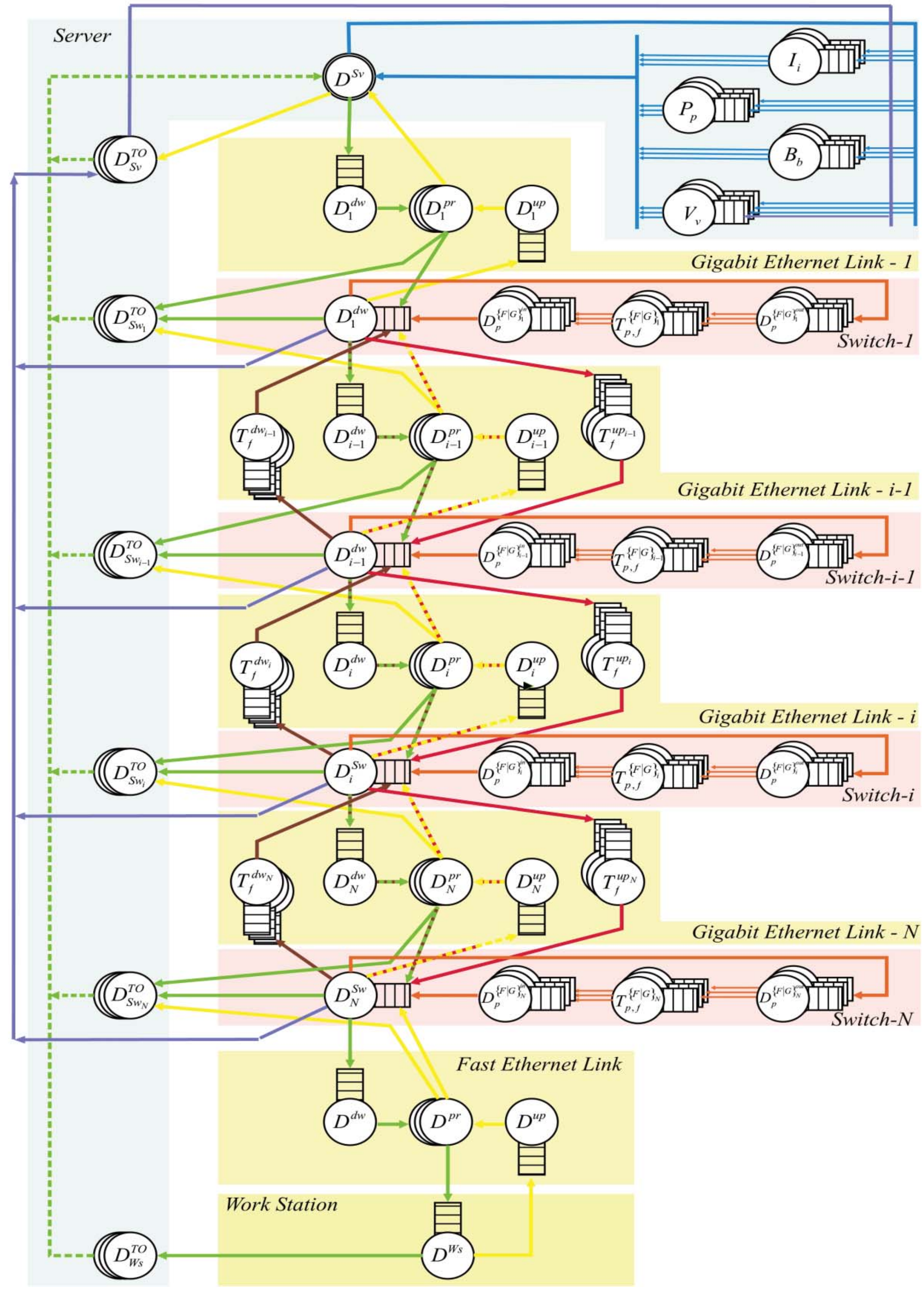


Figure 2. The model structure is the transfer of video traffic over an IP network.

D^{up} - Delays of MAC-frames transmission with encapsulated IP packets transmitted to a video server, Ln^F Fast Ethernet links;

D^{pr} - Delays of signal propagation Ln^F Fast Ethernet links;

D_{Sv}^{TO} - Delays retransmissions of TCP-segments video server due to errors receive IP-packets in a video server Sv;

$D_{Sw_i}^{TO}$ - Delays retransmissions of TCP-segments video server due to errors receive IP-packet switch Sw$_i$, $i = \overline{1, N}$;

D_{Ws}^{TO} - Delays retransmissions of TCP-segments video server due to errors in receiving IP packets workstation Ws;

$D_p^{F_i^{in}}$ - Delays receiving Sw$_i$ switch MAC-frames received via its input Fast Ethernet port number p. Traffic of these MAC-frames due background traffic; Λ_i^F, $p = \overline{1, N_i^F}$, $i = \overline{1, N}$

$D_p^{G_i^{in}}$ - Delays of MAC-frames receiving Swi switch coming through his incoming Gigabit Ethernet port number p. Traffic of these MAC-frames due background traffic; Λ_i^G, $p = \overline{1, N_i^G}$, $i = \overline{1, N}$

$D_p^{F_i^{out}}$ - Delays of MAC-frame transmission Sw$_i$ Switch through its outbound Fast Ethernet port number p. Traffic of these frames is due to the incoming background traffic; $\Lambda_i^G \;\; u \;\; \Lambda_i^F$, $p = \overline{1, N_i^F}$, $i = \overline{1, N}$

$D_p^{G_i^{out}}$ - Delays of MAC-frame transmission Sw$_i$ Switch through its outgoing Gigabit Ethernet port number p. Traffic of these frames is due to the incoming background traffic; $\Lambda_i^G \;\; u \;\; \Lambda_i^F$, $p = \overline{1, N_i^G}$, $i = \overline{1, N}$

$T_f^{up_i}$ - The time interval between two consecutive data blocks background traffic $\Lambda_{x_f}^{up_i}$, the average size of which is equal to x_f bytes; $x_f \in S_i^{up}$, $f = \overline{1, L_i^{up}}$, $i = \overline{1, N-1}$

$T_f^{dw_i}$ - The time interval between two consecutive data blocks background traffic $\Lambda_{x_f}^{dw_i}$, the average size of which is equal to x_f bytes; $x_f \in S_i^{dw}$, $f = \overline{1, L_i^{dw}}$, $i = \overline{1, N-1}$

$T_f^{G_i}$ - The time interval between two consecutive data blocks background traffic $\Lambda_{x_f}^{G_i}$, the average size of which is equal to x_f bytes; $x_f \in S_i^G$, $f = \overline{1, L_i^G}$, $i = \overline{1, N}$.

$T_f^{F_i}$ - The time interval between two consecutive data blocks background traffic $\Lambda_{x_f}^{F_i}$, whose average size is x_f bytes; $x_f \in S_i^F$, $f = \overline{1, L_i^F}$, $i = \overline{1, N}$.

C. *Description of classes network model*

Requirement class network model displays a set of similar items of information flows that are transmitted over the telecommunications system being modeled. These elements are, for example, the video frame of the appropriate type and size, data block background traffic, TCP segment, IP packet or MAC frame that encapsulates the appropriate video frame or data block background traffic, a receipt for the corresponding TCP segment. The transfer of items of information-tional flow, according to the protocol used, these elements can change their class.

Classes of requirements are:

I_i^0 - To display the I_{xi} frame in the video stream, the average size of which is equal to x$_i$ bytes, or IP packet (MAC frame) encapsulated in it that I frame, while it was not the case of retransmissions; $x_i \in S_I$, $i = \overline{1, L_I}$

P_p^0 - To display the P_{xp} frame in the video stream, which is equal to the average size of x$_p$ bytes, or IP packet (MAC frame) encapsulated in it that P frame, while it was not the case of retransmissions; $x_p \in S_P$, $p = \overline{1, L_P}$

B_b^0 - To display the B_{xb} frame in the video stream, which is equal to the average size of bytes, or IP packet (MAC frame) encapsulated in it this B frame, while it was not the case of retransmissions; $x_b \in S_B$, $b = \overline{1, L_B}$

I_i^j - To display the IP packet (MAC frame) encapsulated I_{xi} therein-frame, the average size of which is equal x$_i$ bytes, this involved a j its retransmission; $j = \overline{1, J(x_i)}$, $x_i \in S_I$, $i = \overline{1, L_I}$

P_p^j - To display the IP packet (MAC frame) encapsulated P_{xp} therein-frame, the average size of which is equal x$_p$ bytes, this involved a j its retransmission; $j = \overline{1, J(x_p)}$, $x_p \in S_P$, $p = \overline{1, L_P}$

B_b^j - To display the IP packet (MAC frame) encapsulated B_{xb} therein-frame, the average size of which is equal x$_b$ bytes, this involved a j its retransmissions. $j = \overline{1, J(x_b)}$, $x_b \in S_B$, $b = \overline{1, L_B}$

I_i^d - To display the IP packet (MAC frame) encapsulated therein, a I_{x_i} frame, which is equal to the average size of x_i bytes, while the frame itself is brought to the workstation; $x_i \in S_I$, $i = \overline{1, L_I}$

B_b^d - To display the IP packet (MAC frame) encapsulated therein, a B_{x_b} frame, which is equal to the average size of x_b bytes, while the frame itself is brought to the workstation; $x_b \in S_B$, $b = \overline{1, L_B}$

P_p^d - To display the IP packet (MAC frame) encapsulated therein, a P_{x_p} frame, which is equal to the average size of x_p bytes, while the frame itself is brought to the workstation; $x_p \in S_P,\ p = \overline{1, L_P}$

$\dot{I}_i^j$ - To display the IP packet (MAC frame) encapsulated therein TCP segment, which is delivered to the receipt-I_{x_i} frame, the average size of which is equal x_i bytes, this involved a j retransmissions; $j = \overline{1, J(x_i)},\ x_i \in S_I,\ i = \overline{1, L_I}$

$\dot{B}_b^j$ - To display the IP packet (MAC frame) encapsulated therein TCP segment, which is delivered to the B_{x_b} receipt-frame, the average size of which is equal x_b bytes, this involved a j retransmissions; $j = \overline{1, J(x_b)},\ x_b \in S_B,\ b = \overline{1, L_B}$

$\dot{P}_p^j$ - To display the IP packet (MAC frame) encapsulated therein TCP segment, which is delivered to the P_{x_p} receipt-frame, the average size of which is x_p equal bytes, this involved a j retransmissions; $j = \overline{1, J(x_p)},\ x_p \in S_P,\ p = \overline{1, L_P}$

$\dot{I}_i^d$ - To display the IP packet (MAC frame) encapsulated therein TCP segment, which is delivered on the receipt, but not acknowledged I_{x_i} -frame, the average is equal to the average size of x_i bytes; $x_i \in S_I,\ i = \overline{1, L_I}$

$\dot{B}_b^d$ - To display the IP packet (MAC frame) encapsulated therein TCP segment that is a receipt for delivered but not acknowledged- B_{x_b} frame, the average is equal to the average size of x_b bytes $x_b \in S_B,\ b = \overline{1, L_B}$;

$\dot{P}_p^d$ - To display the IP packet (MAC frame) encapsulated therein TCP segment, which is delivered on the receipt, but not acknowledged- P_{x_p} frame The mean size equal xp bytes $x_p \in S_P,\ p = \overline{1, L_P}$;

$T_{p,f}^{G_i}$ - To display the IP packet (MAC frame) encapsulated therein background data block traffic $\Lambda_{p,x_f}^{G_i}$ coming into the switch Sw_i via its Gigabit Ethernet port number p, $x_f \in S_p^{G_i}$, $p = \overline{1, N_i^G}$, $f = \overline{1, L_p^{G_i}}$, $i = \overline{1, N}$;

$T_{p,f}^{F_i}$ - To display the IP packet (MAC frame) encapsulated therein background data block traffic $\Lambda_{p,x_f}^{F_i}$ coming into the switch Sw_i through its Fast Ethernet port number p, $x_f \in S_p^{F_i}$, $p = \overline{1, N_i^F}$, $f = \overline{1, L_p^{F_i}}$, $i = \overline{1, N}$;

$T_f^{up_i}$ - To display the IP packet (MAC frame) encapsulated therein a block of data background traffic sent from the switch to the switch through the communication Ln_i^G , $x_f \in S^{up_i}$, $f = \overline{1, L_i^{up}}$, $i = \overline{2, N}$;

$T_f^{dw_i}$ - To display the IP packet (MAC frame) encapsulated therein data block background traffic sent from the switch to the switch through the communication Ln_i^G , $x_f \in S^{dw_i}$, $f = \overline{1, L_i^{dw}}$, $i = \overline{2, N}$.

Transitions requirements from class I_i^j to class I_i^{j+1}, $j = \overline{0, J(x_i) - 1}$, start retransmission model I_{x_i} - frame after receiving an error in the appropriate communication equipment.

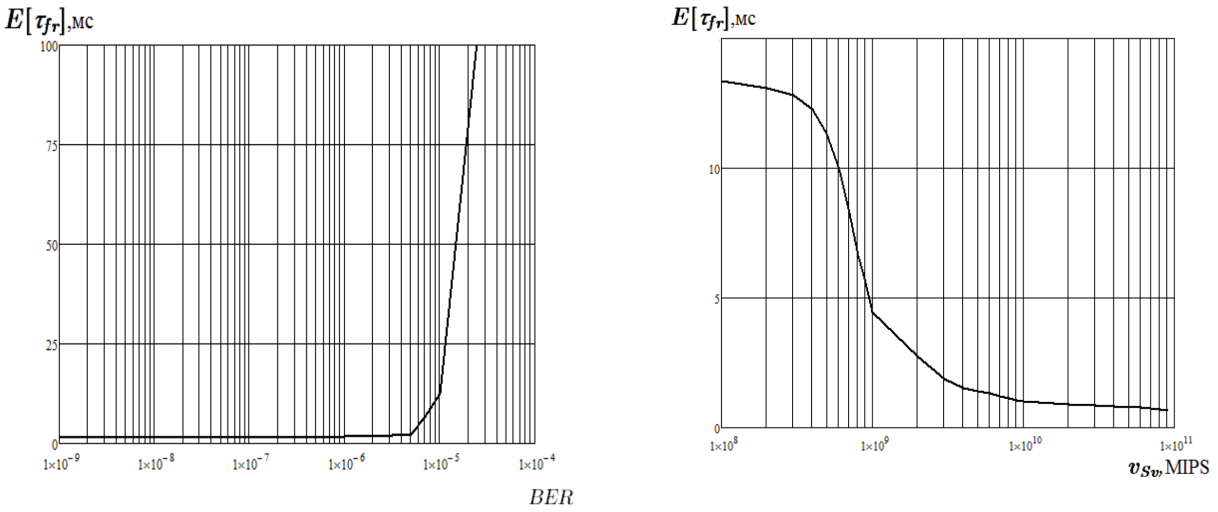
IV. RESULTS OF SIMULATION

For the mathematical modeling of multimedia data transmission via IP-network programming environment Mathcad has been used. Figures 3 and 4 show the results of modeling - quality of service parameters in the transmission of inhomogeneous multimedia traffic in a network of TCP/IP, depending on the characteristics of the communication equipment.

The dependences 2 (a) and 3 (a) show that increasing the probability of bit errors in the channel Gigabit Ethernet to a value of 10-5 of the transmission characteristics (one-way delay and delay variation - jitter) become worse and its quality becomes unacceptable.

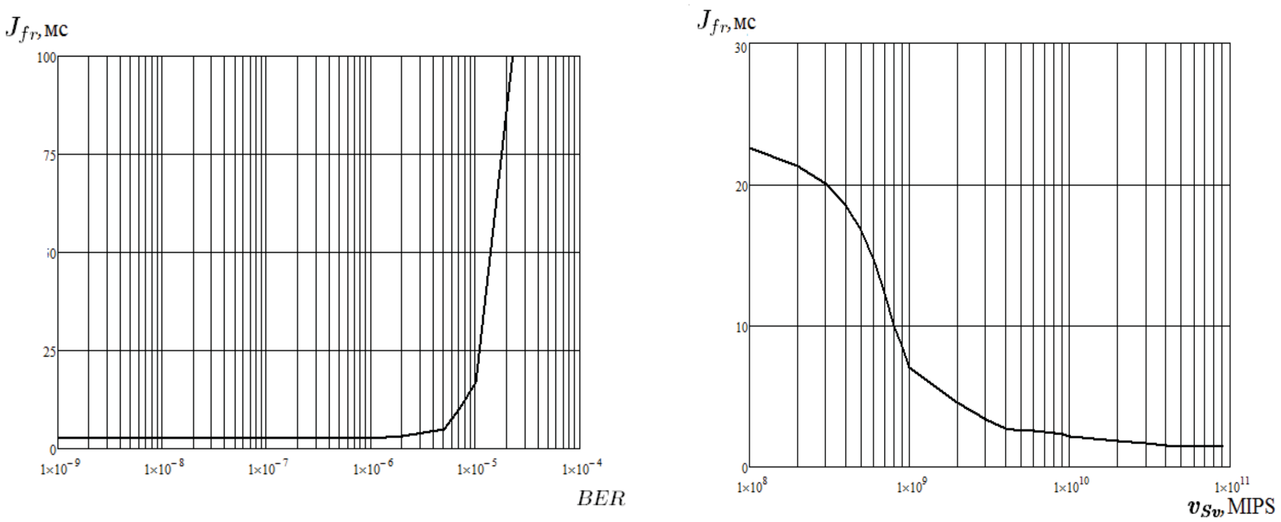
Figures 2 (b) and 3 (b), we can see how are reducing one-way delay and jitter with the increase in server performance. From these graphs it is clear that in order to ensure the required quality of service Video on Demand, you must use a sufficiently powerful computer systems that can quickly handle requests.

Thus, the data can be used to choose the right equipment to provide high-quality transmission video stream from the server to the customers



a b

Figure 3. The dependence of the one-way delay: a) - on the intensity bit error rate; b) - on the performance of the server.



a b

Figure 4. Dependence of jitter: a) - the intensity of the bit error rate, b) - the performance of the server

V. CONCLUSION

In this paper, a method of mathematical modeling of communication networks is proposed in order to estimate the quality of service that is based on the use of inhomogeneous closed queuing networks of large dimensionality. The method is to display different information flows in a simulated telecommunications system by different classes of applications and different delays of data elements relevant information flow queuing. The possible combinations of the delay elements of the information flows are defined applications possible transitions corresponding classes.

Probabilistic-time characteristics of the simulated telecommunications system we calculated according to the expressions for the delays developed in inhomogeneous closed queuing networks [13]. To calculate the parameters of queuing networks the method of analysis medium is applied [13-14].

As an example, a mathematical model was developed to estimate the QoS parameters of transmission inhomogeneous multimedia traffic in IP networks. For this case data one-way delay and jitter were obtained.

The results showed the possibility and high efficiency of applications inhomogeneous closed queuing networks of large dimensionality as a method of mathematical modeling of different communication systems.

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