HYBRID MODEL MANAGEMENT OF INFORMATION MESSAGES IN MULTISERVICE NETWORKS

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Abstract: Problems of multiservice network modeling on the basis of hybrid methods – methods of graph theory and queue system are considered in the article. Model NGN-network is presented in the form of exponential Petri net. For calculation of probabilistic and time characteristics of network on the basis of Petri net analytical expression was received. On the basis of this expression calculation of time allocation density of message transfer that depends on special points' allocation of distribution function is executed. The model can be used for the study information processes in multiservice telecommunication networks, in development of new protocols, algorithms and control programs of channel resources in NGN-networks. The use of exponential stochastic models of Petri net will give the opportunity of results use received in analytical form (functions, distribution density) for conducting comparative analysis and researches, more complicated information-telecommunication system by mathematical methods.

Keywords: modeling, graph, Petri net, NGN network, message transfer, information flow, exponential distribution, multiservice network, probabilistic and time characteristics, hybrid model.

Nowadays with development of information technologies, complication and enhancement of telecommunication systems software and mathematical support there is a necessity in elaboration of new data exchange and processing protocols.

Still there are a number of problems connected with reliability determination of multiservice network, evaluation of probabilistic and time characteristics and other solvable with support of mathematical models. The analysis has shown that currently in mathematical modeling of information and telecommunication systems problem solving number of approaches are being used and more effective ones are based on use of graph models and calculation combinatorial methods, flow models and analysis methods of networks, neural networks, tensor models and also Markoff controlled random processes apparatus (Maynika, 1981; Pritsker, 1979; Semenov, 2005; Vishnevskiy, 2003).

Each of the methods has distinct advantages and disadvantages. This case specifies solution of the set task via hybrid models based on use of graph and queue system models. Simplicity of graph models and also Markoff controlled random processes apparatus in the aggregate with nonstandard modeling approaches allows in present to use the successfully in study of statistic processes in telecommunication systems and networks.

In the work for problem solving evaluation of probabilistic and time characteristics graph-analytical model in the form of Petri net is suggested (Semenov, 2008, p.162-165).

In using of these models functioning system process one can see state transitions defining distinct events. Every state corresponds with definite probability. Transition system from one state to another is connected with execution of some operations described by random quantity with known distribution law.

The carried out researches of data transfer in multiservice communication channels have shown that time of frame rates, information packets, protocol messages of transport layer and NGN network access level can be described by exponential distributions or Erlang distribution (Semenov, 2008; Velichko et al., 2005). In Petri net all arcs are characterized by exponential distributions, exponential Petri networks. In this case the final result will be presented in the form of analytical expression which allows to use methods of queue system.

The process of data and message transfer in multiservice communication channel on the basis of Petri net is presented in figure 1.
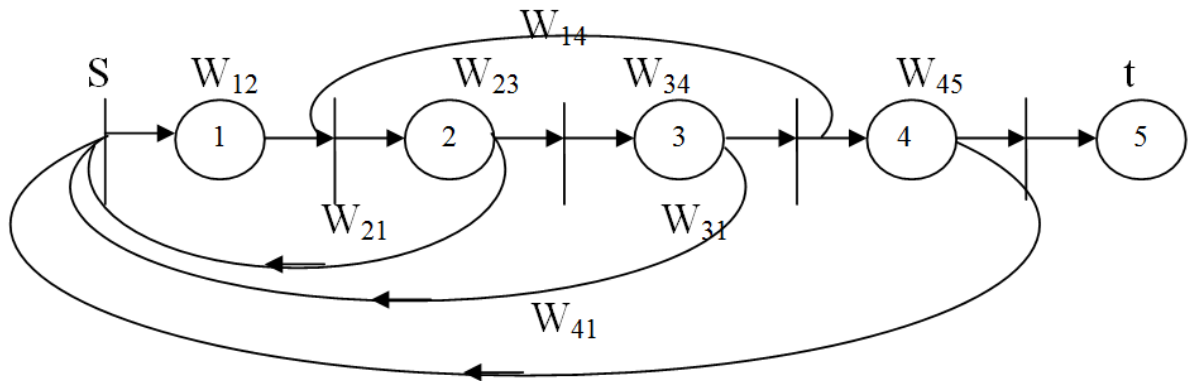

Fig. 1. Algorithm model of message transfer in multiservice communication channel.

In the presented network graph junctions are interpreted by communication link states, and graph branches by probabilistic and time characteristics. The most important feature of the multiservice information transfer process in NGN networks is use of the transport layer protocol spectrum and access level. Specifically it concerns the use of TCP and UDP protocols in compliance with the set of used network applications. On fig. 1 the branch (1, 2) characterizes the time of frame rate transfer (information packet) from transmitter to receiver. In the state 2 continuity test of received data and evaluation of command windows on the subject of their compliance with given requirements. Branches (2, 3); (2, 1) fit the TCP protocol operation mode and set random time of acknowledgement characters transfer about the result of accuracy control of frame rate transfer from receiver to transmitter.

Junction 3 reflects the system state at the moment of frame number check. In this state it is possible to define whether the received frame is intermediate or last in transmitted message. If the received frame is intermediate then corresponding to this system state information in the form of acknowledgement character is transmitted to the transmitter (branch (3, 1)). If the received frame is last in the message then system attaches the frame to the common set of received frames and executes message gatherings in compliance with frame numbers. Random time of frame gatherings is set by branches (3, 4). Results of message gatherings in the form of corresponding acknowledgment characters are transmitted to the transmitter which corresponds to the branches (4, 1). Successful message gatherings transfer the system into the ready condition 5. In data transfer in compliance with algorithms of UDP protocol data transfer processing, motion of frames in the presented graph corresponds to the branches (1, 4), it is supposed that choice probability of arc is known. Branches (2, 3); (2, 1); (3, 1); (3, 4) and (4, 1) can be characterized by one and the same distribution parameter as the set similar operations of service information transfer from receiver to transmitter. Characteristics of branches models are presented in table 1.

Equivalent W- function of message transfer time equals:

$$W_E(s) = (W_{14}\,W_{45} + W_{12}W_{23}W_{34}W_{45})/(1 - W_{12}W_{21} - W_{12}W_{23}W_{31} - W_{12}W_{21}W_{34}W_{41} - W_{14}W_{41}) =$$

$$= \frac{p_4\lambda_4(\lambda_3 - s)\big(\ q_1\lambda_1(\lambda_2 - s)(\lambda_3 - s)^2 + p_1p_2p_3\lambda_2\lambda_3^2(\lambda_1 - s)\ \big)}{(\lambda_4 - s)\left(p_1\lambda_2\lambda_3(\lambda_1 - s)(\lambda_3 - s)^2\left(\dfrac{(\lambda_2 - s)(\lambda_3 - s)}{p_1\lambda_2\lambda_3} - \dfrac{p_2q_3\lambda_3}{\lambda_3 - s} - \dfrac{p_2p_3q_4\lambda_3^2}{(\lambda_3 - s)^2} - \dfrac{q_1q_4\lambda_1(\lambda_2 - s)}{p_1\lambda_2} - q_2\right)\right)},$$

where $1 - p_1 = q_1$; $1 - p_2 = q_2$; $1 - p_3 = q_3$; $1 - p_4 = q_4$.

Features of data transfer process in multiservice communication channel are characterized by heterogeneity of circulating in it information flows and correspondingly with use of different protocols (TCP, UDP and others) of transport layer and access level. Different cases of feedback organization (cycles sender-receiver-sender) are possible via service messages (TCP protocol). On the fig.1 these cycles are fixed in the form of transitions:

$$W_{12} \to W_{21}; \quad W_{12} \to W_{23} \to W_{31}; \quad W_{12} \to W_{23} \to W_{34} \to W_{41}; \quad W_{14} \to W_{41}.$$

$$\Phi(z) = \frac{uz^3 + wz^2 + vz + h}{(\lambda_1 + z)(\lambda_3 + z)(\lambda_4 + z)(z^3 + az^2 + bz + c)};$$

where $w = q_1\lambda_1(\lambda_2 + 2\lambda_3)$; $h = \lambda_1\lambda_2\lambda_3^2(q_1 + p_1p_2p_3)$; $v = \lambda_3(q_1\lambda_1(2\lambda_2 + \lambda_3) + p_1p_2p_3\lambda_2\lambda_3)$;

$u = q_1\lambda_1$; $a = 2\lambda_3 + \lambda_2 - \dfrac{q_1q_4\lambda_1\lambda_3}{\lambda_1 + z}$;

$$b = \lambda_3\left(\lambda_3 + 2\lambda_2 - p_1q_2\lambda_2\lambda_3 - \frac{q_1q_4\lambda_1\lambda_3(\lambda_3 + \lambda_2)}{\lambda_1 + z} - \frac{p_1p_2q_3\lambda_2\lambda_3^2}{\lambda_3 + z}\right);$$

$$c = \lambda_2\lambda_3^2\left(1 - p_1q_2 - \frac{q_1q_4\lambda_1}{\lambda_1 + z} - \frac{p_1p_2\lambda_3(q_3 + q_4)}{\lambda_3 + z}\right).$$

Table

Features of model branches

№	Branch	W-function	Probability	Moment-generating function
1	(1,2)	W12	p1	$\lambda_2 / (\lambda_2 - s)$
2	(1,4)	W14	1-p1	$\lambda_1 / (\lambda_1 - s)$
3	(2,3)	W23	p2	$\lambda_3 / (\lambda_3 - s)$
4	(2,1)	W21	1-p2	$\lambda_3 / (\lambda_3 - s)$
5	(3,1)	W31	1-p3	$\lambda_3 / (\lambda_3 - s)$
6	(3,4)	W34	p3	$\lambda_3 / (\lambda_3 - s)$
7	(4,1)	W41	1-p4	$\lambda_3 / (\lambda_3 - s)$
7	(4,5)	W45	p4	$\lambda_4 / (\lambda_4 - s)$

Density of message transfer probability time distribution:

$$\varphi(x) = (2\pi i)^{-1}\int_{-i\infty}^{i\infty} e^{zx}\frac{uz^3 + wz^2 + vz + h}{(\lambda_1 + z)(\lambda_3 + z)(\lambda_4 + z)(z^3 + az^2 + bz + c)}\,dz,$$

where integration operation is executed with the help of Bromvich-Vagner integral (Pritsker, 1979).

The integration method depends on whether function $\Phi(z)$ has only simple poles or poles of some orders. In case when function $\Phi(z)$ has only simple poles then expression $e^{zx}\Phi(z)$ can be presented in the form:

$$e^{zx}\Phi(z) = \frac{e^{zx}(uz^3 + wz^2 + vz + h)}{z^6 + g_5z^5 + g_4z^4 + g_3z^3 + g_2z^2 + g_1z + g_0)} = \frac{\mu(z)}{\psi(z)},$$

where $g_5 = a + \lambda_1 + \lambda_3 + \lambda_4$; $g_4 = b + a(\lambda_1 + \lambda_3 + \lambda_4) + \lambda_3\lambda_4 + \lambda_1\lambda_4 + \lambda_1\lambda_3$;

$g_3 = c + b(\lambda_1 + \lambda_3 + \lambda_4) + a(\lambda_3\lambda_4 + \lambda_1\lambda_4 + \lambda_1\lambda_3) + \lambda_1\lambda_3\lambda_4$;

$g_2 = a(\lambda_1\lambda_3\lambda_4) + b(\lambda_3\lambda_4 + \lambda_1\lambda_4 + \lambda_1\lambda_3) + c(\lambda_1 + \lambda_3 + \lambda_4)$;

$g_1 = b(\lambda_1\lambda_3\lambda_4) + \lambda_3\lambda_4 + \lambda_1\lambda_4 + \lambda_1\lambda_3$; $g_0 = c(\lambda_1\lambda_3\lambda_4)$.

Then density of message transfer distribution time equals:

$$\varphi(x) = \sum_{k=1}^{6}\operatorname{Re}s[e^{zx}\Phi(z)] = \sum_{k=1}^{6}\frac{\mu(z_k)}{\psi(z_k)} = \sum_{k=1}^{6}\frac{e^{zx}(uz_k^3 + wz_k^2 + vz_k + h)}{6z_k^5 + 5g_5z_k^4 + 4g_4z_k^3 + 3g_3z_k^2 + 2g_2z_k + g_1}$$

Function $\Phi(z)$ besides simple poles defining by equation root $yz^3 + az^2 + bz + c = 0$ can have both poles of second and third order. It is possible in those cases when values λ_1, λ_3 and λ_4 coincide with each

other or equal to the root value $z_3; z_4; z_5; z_6$. In this case density of message transfer distribution time $\varphi(x)$ is according to the formula of calculation finding r_{-1} from poles z_k of n order:

$$r_{-1} = \frac{1}{(n-1)!} \lim_{z \to z_k} \frac{d^{n-1}((z-z_k)^n e^{zx} \Phi(x))}{dz^{n-1}}$$

Expression 1 presents fractional rational function concerning z with more denominator degree than numerator degree. That is why condition of Jordan lemma is executed for it (Pritsker, 1979).

Function $\Phi(z)$ has poles in points $z_1 = -\lambda_1;\ z_2 = -\lambda_3;$ and $z_3 = -\lambda_4$. Polynomial $yz^3 + az^2 + bz + c$ generates more three poles. Solution of the equation $yz^3 + az^2 + bz + c = 0$ can be found by any method, for example, according to Vieta formulas. As a result three more special points z_3, z_4, z_5 are calculated.

Thus, on the basis of Petri exponential net mathematical model of multiservice communication channel is elaborated. It differs from known ones by procedures accounting of information exchange with possible cycles in compliance with protocols of transport layer and NGN network access level. The model can be used for the study information processes in multiservice telecommunication networks, in development of new protocols, algorithms and control programs of channel resources in NGN-networks.

The use of exponential stochastic models of Petri net will give the opportunity of results use received in analytical form (functions, distribution density) for conducting comparative analysis and researches, more complicated information-telecommunication system by mathematical methods.

References

Maynika, E. and Maslovskij, Y. (ed.) (1981) *Algoritmy optimizasii na setyax i grafax*, Moscow: Mir.

Pritsker, A. (1979) *Modeling and analysis using Q-GERT networks*, New York: Wiley.

Semenov, S.G. (2008) 'Raspredelenie kanalnix resursov setevogo oborudovaniya pri informasionnom obmene v edinoy avtomatizirovannoy sisteme upravleniya', *Radioelektronniy i Kompyuterniy Sistemi,* 33(6), pp. 307-310.

Semenov, S. et al. (2005) 'Razrabotka raspredelennogo metoda mnogoputevoy marshrutizasii, osnovannogo na potokovoy modeli s predvichislennim putey (marshrutov)', *Modelirovaniya na Informasionni Tehnologii,* 2005(32), pp. 189-192.

Semenov, S. and Ilina, I. (2008) 'Matematicheskaya model prosessa dostavki informasionnix paketov v kompyuternoy seti i sistemi kriticheskogo primeneniya', *Radioelektronniy i Kompyuterniy Sistemi,* 28(1), pp. 162-165.

Velichko, V. (2005) *Telekommunikatsionnie sistemi i seti. Volume 3*, Moscow: Goryachayaliniya-Telekom.

Vishnevskiy, V. (2003) *Teoritechiskie osnovi proektirovaniya kompyuternix setey*, Moscow: Texnosfera.