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Performance Analysis of Unreliable Internet Node

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Introduction

Analysis of an unreliable asymmetric M/M/2 network node, which is a Markov birth and death system, may be obtained by applying the general solution given by Bolch G. and other authors [1, 2, 3]. Our proposed data packets loss or blocking system node with different bit rates channels model can be used to investigate processes of the Poisson, Pareto, Weibull and others arrival flow of messages or packets in the data networks. In symmetric system the response time depends only on whether an arrival packet finds a free channel, but in an asymmetric system it differs because the channels transmission bit rates are not equal and depend on which of the channels transmits the packet [4].

In this paper we study asymmetric unreliable system with losses by means of analytical and simulation method. We will study an efficient way how to model such system by means of Moore and Mealy automata [5]. In this article we propose the data network node forwarding data packets to channels with different bit rate each.

Our paper proposes the analytical and simulation models of two channels asymmetric unreliable system with packet losses and delay when the channel with larger bit rate is occupied with probability p, and the second channel is selected with probability ($1-p$). Analysis of such data networks nodes is currently an active area of research [6].

An accurate modeling of the offered data network traffic load is the first step in optimizing network resources. Quality of service (QoS) in our model is expressed in such parameters: packet losses, system utilization parameter, channels utilization parameters.

Analytical model for asymmetric unreliable Internet node performance evaluation

We will investigate the telecommunication network node consisting of two unreliable service channels and servicing Poisson data packet flow with losses (Fig. 1).

In this section we present analytical model of data packets transmission processes in an asymmetric unreliable channels Internet node.

Consider the Poisson data packet arrival flow with rate equal λ, each channel data packets transmission intensities consequently are equal μ_1, μ_2. Each channel failure rates are γ_1, γ_2 and mean times to failure are exponentially distributed. Let the repair rates for each transmission channel equal r_1, r_2 with exponentially distributed repair times.

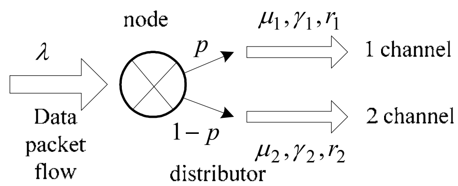

Fig. 1. The main processes for network node consisting of two unreliable transmission channels

Incoming data packet flow to the node is distributed according to Poisson distribution with parameter λ and the data packet length is exponentially distributed.

The mean value of data packet transmission duration via each channel is given by $\bar{\tau}_1 = 1/\mu_1$, $\bar{\tau}_2 = 1/\mu_2$. In such case the data packet transmission time in each channel is distributed exponentially with mean value of time $\bar{\tau}_i = 1/\mu_i$, $P\{\tau_i \le t\} = 1 - e^{-\mu_i t}$; $i = 1,2$, $0 \le t < \infty$.

The intensity of data packet transmission in system is given by $\mu = \mu_1 + \mu_2$. The system utilization is given $\rho = \lambda/\mu$. The Markov birth-death model is used for calculating performance characteristics of two channels loss system. Each system state may be described by vector of four parameters $X\ Y\ Q\ Z$, where

$$X = \begin{cases} 1 & \text{I channel bussy,} \\ 0 & \text{I channel free,} \end{cases} \quad Y = \begin{cases} 1 & \text{II channel bussy,} \\ 0 & \text{II channel free,} \end{cases}$$

$$Q = \begin{cases} 1 & \text{I channel faulty,} \\ 0 & \text{I channel operable,} \end{cases} \quad Z = \begin{cases} 1 & \text{II channel faulty,} \\ 0 & \text{II channel operable.} \end{cases}$$

In such case our system, shown in Fig. 1, can be mapped onto continuous time and discrete state Markov process as shown in Fig. 2.

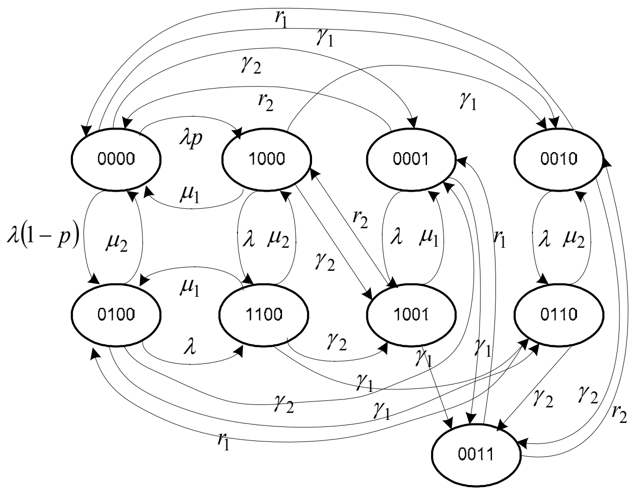

Fig. 2. Graph of the continuous time Markov chains for two unreliable channels network node

Using the global balance concept we can easily write down the following equations for the system state probabilities evaluation:

$$\begin{cases} P_{0000}(\lambda+\gamma_1+\gamma_2)-\mu_1 P_{1000}-\mu_2 P_{0100}-r_1 P_{0010}-r_2 P_{0001}=0, \\ P_{1000}(\lambda+\mu_1+\gamma_1+\gamma_2)-\lambda p P_{0000}-\mu_2 P_{1100}-r_2 P_{1001}=0, \\ P_{0001}(\lambda+\gamma_1+r_2)-\mu_1 P_{1001}-\gamma_2 P_{0000}-r_1 P_{0011}-\gamma_2 P_{0100}=0, \\ P_{0010}(\lambda+\gamma_2+r_1)-\mu_2 P_{0110}-\gamma_1 P_{0000}-\gamma_1 P_{1000}-r_2 P_{0011}=0, \\ P_{0100}(\lambda+\mu_2+\gamma_1+\gamma_2)-\lambda(1-p)P_{0000}-\mu_1 P_{1100}-r_1 P_{0110}=0, \\ P_{1100}(\mu_1+\mu_2+\gamma_1+\gamma_2)-\lambda P_{1000}-\lambda P_{0100}=0, \\ P_{1001}(\mu_1+\gamma_1+r_2)-\lambda P_{0001}-\gamma_2 P_{1000}-\gamma_2 P_{1100}=0, \\ P_{0110}(\mu_2+\gamma_2+r_1)-\lambda P_{0010}-\gamma_1 P_{1100}-\gamma_1 P_{0100}=0, \\ P_{0011}(r_1+r_2)-\gamma_1 P_{1001}-\gamma_1 P_{0001}-\gamma_2 P_{0010}-\gamma_2 P_{0110}=0, \\ \sum_{i,j,k,l} P_{ijkl}=1. \end{cases} \quad (1)$$

To solve (1) equations, we obtain the system states probabilities P_{XYQZ}. We now proceed to find the system performance measures such as:

- data packet loss probability

$$P_{loss} = P_{1100} + P_{0011}; \quad (2)$$

- first and second channel utilizations

$$\begin{cases} \rho_1 = P_{1000} + P_{1100} + P_{1001}, \\ \rho_2 = P_{0100} + P_{1100} + P_{0110}; \end{cases} \quad (3)$$

- the first and the second channels faulty probabilities

$$\begin{cases} P_{1F} = P_{0010} + P_{0110} + P_{0011}, \\ P_{2F} = P_{0001} + P_{1001} + P_{0011}; \end{cases} \quad (4)$$

- both transmission channels faulty probability

$$P_{12F} = P_{0011}. \quad (5)$$

Mainly the data packet transmission quality in such data network node is characterized by packet loss probability, channels utilization and channels faulty probability.

Description of the simulation model of the unreliable Internet node service by the convolution of Moore and Mealy automata

Creating the simulation model for this system (Fig. 1), we will use the method of convolution of Moore and Mealy automata [5].

The conjunction of Moore and Mealy automata will be called the convolution of them (Fig. 3). The following surjections

$$\begin{cases} g_r: \ Y \times W \to W, \quad f_r: \ W \to X, \\ f_l: \ X \times Z \to Y, \quad g_l: \ X \times Z \to Z \end{cases} \quad (6)$$

define the work of this convolution.

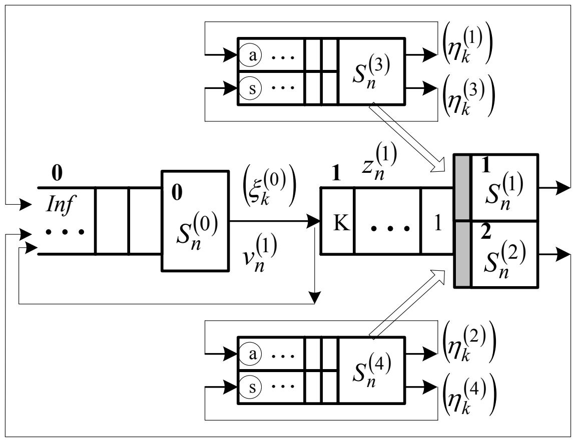

Fig. 3. The imitation model of Internet node with two unreliable channels

A virtual service system (Fig. 3) will be created to simulate this system. It is different from the investigated system (Fig. 1), because it is closed and 0-th service channel with infinite number of packets, being in 0-th buffer, has been placed in it and two additional devices.

Its purpose is to generate the flow of packets to the 1st and 2nd service channels. Such solution of the task lets to interpret everything like the conjunction of the same four Moore and Mealy automata convolutions.

Therefore we will consider that 0-th channel generates the packets, the 1st and 2nd channels execute „the real" servicing of the packets. Infinite number of packets waits at the 0-th channel, and the packets, served in the 1st and 2nd channels, return to the end of the "0-th" channel. If a packet arrived at the 1st channel finds it busy, the packet is dropped. But in the investigated system we have an infinite number of packets all time. Thus we create a close service system. It unifies the creation of surjections that describe the operation of such system.

$\left(\xi_l^{(0)}, l \in Z_0\right)$ - the packets arrive to the system; $\left(\xi_l^{(k)}, l \in Z_0\right), k = 1,2$ - the packets are serving in k-th servicing channel; $\left(\eta_l^{(k)}, l \in Z_0\right), k = 1,2$ - the work period of k-th channels; $\left(\eta_l^{(k)}, l \in Z_0\right), k = 3,4$ - the repair period of (k-2)-th channels.

Consider that the servicing of j-th packet in k-th channel continuous $\xi_j^{(k)}, k = 1,2$ time. Note that 0-th channel, generating the packets, services – generates the packets at time moments $\xi_1^{(0)}, \xi_1^{(0)} + \xi_2^{(0)}, \xi_1^{(0)} + \xi_2^{(0)} + \xi_3^{(0)}, \ldots$, the 1st and 2nd channels service the packets if only they can take the packets from buffer through the times $\xi_j^{(1)}$ and $\xi_j^{(2)}$. Random values $\xi_j^{(k)}, k = 0,1,2,\ j = 1,2,3,...$ are positive, that has been got from generation by selected probabilistic distribution or as statistical values. Consider that, the 1st service channel with probability p takes to serve the packet, if both channels are free at time moment t_n (respectively, the 2nd service channel with probability $1-p$ takes to serve the packet). With such preconditions we will denote the logical variables for system.

The k-th channel works on time periods $\left(\eta_l^{(k)}, k = 1,2\right)$ and the (r-2)-th channel is repairing on time periods $\left(\eta_l^{(r)}, r = 3,4\right)$, when $l \in N$.

We need to introduce the standard variables $S_n^{(k)}, t_n, \chi_n^{(k)}, v_n^{(1)}, \gamma_n^{(k)}$ for creation of surjections that are used in such simulation models [5, 7]. The creation of $v_n^{(1)}$ depends on a concrete model.

Special variables $\chi_n, \beta_n, \beta_n^{(0)}, \beta_n^{(1)}, \beta_n^{(2)}$ for every model are selected individually. The signals and states x_n, y_n, w_n, z_n of Moore and Mealy automata are created using variables $\Theta_n^{(k)}, \Lambda_n^{(k)}$, $\Gamma_n^{(k)}, \vec{T}_n^{(k)}$. The variables $\chi_n^{(k)}, v_n^{(k)}, \gamma_n^{(k)}$, $\chi_n, \beta_n, \beta_n^{(0)}, \beta_n^{(1)}, \beta_n^{(2)}$ are logical variables, that can get two values 0 and 1. The inverse variable for the logical variable A is $\overline{A} = 1 - A$.

We will use the unitary Heaviside function

$$\mathbf{1}(t) := \begin{cases} 0, & t < 0, \\ 1, & t \ge 0 \end{cases}$$

for creating the logical expressions for surjections. We will use the symbol Inf which means the symbol $+\infty$.

We will introduce variables for creation of surjections. Put the case that $n \in N$, $k = 0, 1, 2$. Then:

- t_n – „taimer“ – ($t_0 = 0$, $0 < t_1 < t_2 < \ldots$) it defines the time moment, when any event occurs.
- $S_n^{(k)}, k = 1,2$ – controlling variables, defining the time moment t_{n+1}, when the value t_n is known; $S_n^{(k)}$ can be equal:

a) $\varsigma_n^{(k)}$ - $\left(0 < \varsigma_n^{(k)} < +\infty\right)$ shows, when the k-th servicing channel will finish the serve packets (including the possible repair),
b) Inf - the k-th channel is not repairing and is free,
c) $Inf + \varsigma_n^{(k)}$ - the k-th channel hasn't a packet, but it is repairing and the repair will be finished at time moment $\varsigma_n^{(k)}$.

Other controlling variables $S_n^{(k)}, k = 0,3,4$ can get values $S_n^{(k)} > 0$.

Then the formula

$$t_n := \min\left(S_n^{(k)} \mid k = \overline{0, 4}\right) := = \min\left(S_n^{(0)}, q_n^{(1)}, q_n^{(2)}, S_n^{(3)}, S_n^{(4)}\right), \quad (7)$$

when $q_n^{(k)} = \varsigma_n^{(k)}$, if $S_n^{(k)} = \varsigma_n^{(k)}$ or $S_n^{(k)} = Inf + \varsigma_n^{(k)}$; $q_n^{(k)} = Inf$, if $S_n^{(k)} = Inf$; $k = 1,2$, is used.

- $\chi_n^{(k)}$ – ($\chi_n^{(k)} = -1, 0$) – if $\chi_n^{(k)} = -1$ then k-th channel at time moment t_n finished to serve the packet, and if $\chi_n^{(k)} = 0$, then the servicing is not finished or the channel hasn't worked

$$\chi_n^{(k)} := -\mathbf{1}\left(t_n - S_n^{(k)}\right), k = \overline{0,4}. \quad (8)$$

Note that $\mathbf{1}\left(t_n - S_n^{(k)}\right) := \mathbf{1}\left(t_n - \varsigma_n^{(k)}\right)$, if $S_n^{(k)} = Inf + \varsigma_n^{(k)}, k = 1,2$, otherwise $\mathbf{1}\left(t_n - S_n^{(k)}\right)$ is defining usually.

- $\gamma_n^{(k)}, k = 1,2$ – $\left(\gamma_n^{(k)} = 1, 0\right)$ - if $\gamma_n^{(k)} = 1$, then at time moment t_n the k-th service channel works, and if $\gamma_n^{(k)} = 0$, the the service channel is free. Thus

$$\overline{\gamma}_n^{(k)} := \mathbf{1}\left(S_n^{(k)} - Inf\right), k = 1,2. \quad (9)$$

Note that $\left(Inf + \varsigma_n^{(k)}\right) - Inf = \varsigma_n^{(k)}$, if $S_n^{(k)} := Inf + \varsigma_n^{(k)}$.

- $v_n^{(1)}$ – ($v_n^{(1)} = 0, 1$) – if $v_n^{(1)} = 1$, then the packet arrives at 1st buffer at time moment t_n, and if $v_n^{(1)} = 0$ - there are no arriving packets

$$v_n^{(1)} := -\chi_n^{(0)}; \quad (10)$$

- $z_n^{(1)}$ - defines the number of packets in the 1st buffer:

$$z_n^{(1)} := \left(z_{n-1}^{(1)} + v_n^{(1)} + \chi_n^{(1)}\gamma_n^{(1)} + \chi_n^{(2)}\gamma_n^{(2)}\right) \times \times \mathbf{1}\left(K + 2 - \left(z_{n-1}^{(1)} + v_n^{(1)} + \chi_n^{(1)}\gamma_n^{(1)} + \chi_n^{(2)}\gamma_n^{(2)}\right)\right) + \quad (11) + z_{n-1}^{(1)} \cdot \overline{\mathbf{1}\left(K + 2 - \left(z_{n-1}^{(1)} + v_n^{(1)} + \chi_n^{(1)}\gamma_n^{(1)} + \chi_n^{(2)}\gamma_n^{(2)}\right)\right)}.$$

- $z_n^{(3)}$ - a number of no served packets in system:

$$z_n^{(3)} = z_{n-1}^{(3)} + + \mathbf{1}\left(\left(z_{n-1}^{(1)} + v_n^{(1)} + \chi_n^{(1)}\gamma_n^{(1)} + \chi_n^{(2)}\gamma_n^{(2)}\right) - (K+3)\right). \quad (12)$$

In this case are needed such special variables:

$$\chi_n := \mathbf{1}\left(1 - z_{n-1}^{(1)}\right) \cdot \mathbf{1}\left(z_{n-1}^{(1)} - 1\right); \quad (13)$$

- if $\chi_n = 1$, then the only one packet is in system;

$$\beta_n^{(0)} := \mathbf{1}\left(p - \alpha_{k_n}\right); \quad (14)$$

- if $\beta_n^{(0)} = 1$, then an event occurred in system with probability p, $0 \le p \le 1$ (here α_i - a random values even distributed in interval $(0, 1]$);

$$\overline{\beta}_n^{(0)} := 1 - \beta_n^{(0)}; \quad (15)$$

- if $\overline{\beta}_n^{(0)} = 1$, then an event occurred in system with probability $1 - p$, $0 \le 1 - p \le 1$;

$$\beta_n := v_n^{(1)} \chi_n + \chi_n^{(1)} \chi_n^{(2)} \overline{v}_n^{(1)} \chi_n, \; k_{n+1} := k_n + \beta_n; \quad (16)$$

- if $\beta_n = 1$, then at time moment t_n the only one packet, that has arrived at time moment t_n, is in system, or the packet didn't arrive, but both channels finished serve and the one packet stayed in system;

$$\beta_n^{(1)} := \beta_n^{(0)} \beta_n; \quad (17)$$

- if $\beta_n^{(1)} = 1$ and $\beta_n = 1$, then at time moment t_n the only one packet is in system and it will be served in 1st channel;

$$\beta_n^{(2)} := \overline{\beta}_n^{(0)} \beta_n; \quad (18)$$

- if $\beta_n^{(2)} = 1$ and $\beta_n = 1$, then at time moment t_n the only one packet is in system and it will be served in 2nd channel.

Now we can create the formulas for the surjections f_r, f_l, g_l, g_r. The variables, defining the service regime, will be expressed so:

$$\Theta_n^{(0)} := -\chi_n^{(0)}, \quad (19)$$

$$\Theta_n^{(k)} := \beta_n^{(k)} + \left(\overline{\gamma}_n^{(k)} - \chi_n^{(k)}\right) \cdot \mathbf{1}\left(z_n^{(k)} - 2\right), \; k = 1,2, \quad (20)$$

$$\Lambda_n^{(0)} := 0, \quad (21)$$

$$\Lambda_n^{(k)} := \beta_n^{(l)} - \mathbf{1}\left(1 - z_n^{(1)}\right) \cdot \chi_n^{(k)} \cdot \left(1 + \chi_n^{(l)}\right) \cdot \overline{v}_n^{(1)} +$$
$$+ \mathbf{1}\left(-z_n^{(1)}\right) \cdot \chi_n^{(1)} \cdot \chi_n^{(2)}, \; (k = 1, l = 2), (k = 2, l = 1), \quad (22)$$

$$\Gamma_n^{(k)} := 1 - \Theta_n^{(k)} - \Lambda_n^{(k)}, \; k = 0, 1, 2, \quad (23)$$

$$j_{n+1}^{(k)} := j_n^{(k)} + \Theta_n^{(k)}, \; k = 0, 1, 2. \quad (24)$$

We will describe two vectors $\vec{T}_n^{(k)}$ and $\vec{C}_n^{(k)}$ for creating the controlling sums $\vec{S}_{n+1}^{(k)}$. Then $\vec{S}_n^{(k)} := \left(\vec{T}_n^{(k)}, \vec{C}_n^{(k)}\right)$.

$$\vec{T}_n^{(k)} = \left(t_n + \xi_{j_n^{(k)}}^{(k)}; Inf; S_n^{(k)}\right), \; k = 0, 1, 2, \quad (25)$$

$$\vec{C}_n^{(k)} = \left(\Theta_n^{(k)}, \Lambda_n^{(k)}, \Gamma_n^{(k)}\right), \; k = 0, 1, 2. \quad (26)$$

The work of repairing channel corrects the work of system. The repair in k-th ($k = 1,2$) channel begins when $\tau_n^{(k)} := \frac{1 + (-1)^{m_n^{(k)} + 1}}{2} = 1$ and finishes when $\overline{\tau}_n^{(k)} := \frac{1 + (-1)^{m_n^{(k)}}}{2} = 1$. Lets $\sigma_n^{(k)} = \frac{1}{2}\left(m_n^{(k)} + 1\right) \cdot \tau_n^{(k)}$ and $\overline{\sigma}_n^{(k)} = \frac{1}{2} m_n^{(k)} \cdot \overline{\tau}_n^{(k)}, k = 1,2$.

The description of the work and repair of channels

$$S_{n+1}^{(l)} = -\chi_n^{(l)}\left(t_n + \eta_{\sigma_n^{(k)}}^{(k)} + \eta_{\overline{\sigma}_n^{(k)}}^{(l)}\right) + \left(1 + \chi_n^{(l)}\right) S_n^{(l)}, \quad (27)$$

when $(k = 1, l = 3)$ and $(k = 2, l = 4)$.

Let the sum $\oplus$ defines as follows:

$$S_{n+1}^{(k)} \oplus \eta_{\overline{\sigma}_n^{(k)}}^{(l)} := S_{n+1}^{(k)} + \eta_{\overline{\sigma}_n^{(k)}}^{(l)}, \text{ if } S_{n+1}^{(k)} < +\infty,$$

$$S_{n+1}^{(k)} \oplus \eta_{\overline{\sigma}_n^{(k)}}^{(l)} := Inf + \eta_{\overline{\sigma}_n^{(k)}}^{(l)} + t_n, \text{ if } S_{n+1}^{(k)} = Inf, \quad (28)$$

when $(k = 1, l = 3)$ and $(k = 2, l = 4)$. Lets:

$$\Theta_n^{(l)} = \tau_n^{(k)} \cdot \left(-\chi_n^{(l)}\right), \quad (29)$$

$$\Lambda_n^{(l)} = \overline{\tau}_n^{(k)} \cdot \left(-\chi_n^{(l)}\right) \cdot \overline{\gamma}_n^{(k)}, \quad (30)$$

$$\Gamma_n^{(l)} := 1 - \Theta_n^{(l)} - \Lambda_n^{(l)}. \quad (31)$$

Then $S_{n+1}^{(k)}, k = 1,2$ are correcting so:

$$S_{n+1}^{(k)} = \Theta_n^{(l)} \cdot \left(S_{n+1}^{(k)} \oplus \eta_{\overline{\sigma}_n^{(k)}}^{(l)}\right) + \Lambda_n^{(l)} \cdot Inf + \Gamma_n^{(l)} \cdot S_{n+1}^{(k)}, \quad (32)$$

$$m_{n+1}^{(k)} = m_n^{(k)} - \chi_n^{(l)}, \quad (33)$$

when $(k = 1, l = 3)$ and $(k = 2, l = 4)$.

The surjections will be defined using the recursion formulas in such order f_r, f_l, g_l, g_r.

$$f_r(w_n) = x_n, \quad (34)$$

$$x_n = \left(t_n; v_n^{(1)}; \chi_n^{(0)}, ..., \chi_n^{(4)}, \chi_n\right), \; x_n \in X, \quad (35)$$

$$f_l(x_n, z_{n-1}) = y_n, \quad (36)$$

$$y_n = \left(t_n; v_n^{(1)}; \chi_n^{(0)}, ..., \chi_n^{(4)}; z_n^{(1)}, z_n^{(3)}\right), \; y_n \in Y, \quad (37)$$

$$g_l(x_n, z_{n-1}) = z_n, \; z_n = \left(z_n^{(1)}, z_n^{(3)}\right), \; z_n \in Z, \quad (38)$$

$$g_r(w_n, y_n) = w_{n+1}, w_n = \left(S_n^{(0)}, ..., S_n^{(4)}\right), \; w_n \in W. \quad (39)$$

Consider that the initial states of the automata system are:

$$z_0^{(1)} = 0, \; z_0^{(3)} = 0, \; \left(z_0^{(1)}, z_0^{(3)}\right) = z_0, \quad (40)$$

$$\left(\xi_1^{(0)}, Inf, Inf, \eta_1^{(1)}, \eta_1^{(2)}\right) = w_1, \quad (41)$$

$$m_0^{(1)} = 1, \; m_0^{(2)} = 1, \; j_0^{(k)} = 1, k = 0,1,2, \; n = 1. \quad (42)$$

During simulation the variable n can get values $n = \overline{1, N}$.

The calculation program can be created from the relationships (7-33, 40-42), executing the special reconstructions, that the calculation procedures would be faster and realized with smallest errors.

Note that:

a) if K is changed into Inf, we will have infinite 1st buffer against the 1st and 2nd channels. Then $\mathbf{1}\left(Inf - \left(z_{n-1}^{(1)} + v_n^{(1)} + \chi_n^{(1)}\gamma_n^{(1)} + \chi_n^{(2)}\gamma_n^{(2)}\right)\right) \equiv 1$ and

$$z_n^{(1)} = z_{n-1}^{(1)} + v_n^{(1)} + \chi_n^{(1)}\gamma_n^{(1)} + \chi_n^{(2)}\gamma_n^{(2)}. \qquad (43)$$

b) If $p = 1$, then we will have a service system when 1st channel will have priority against 2nd channel [7].

For calculation of system characteristics (probabilities of data packet loss, mean values of queue length, mean values of data packet delay in the buffer and others) we use the values $(n, t_n, z_n), n = 0,1,2,...$, they are calculated by formulas (1-6) of analytical model too, when we have the estimates of probabilities. The estimate of probability, that in system will be k packets, is calculated by formula $p_k = \frac{T_k}{T}$, when T_k is a time interval when k packets are in system (i.e. Mealy automaton was in the state $z^{(1)} = K$), T - the duration of system work, i.e. $T_0 + T_1 + ... = T$.

Case study

The corresponding numerical results we have obtained applying our proposed methods of data packets transmission in an unreliable data network node which architecture is shown in Fig. 1.

It is possible to evaluate how a different probability p for selecting a free channel in system affects transmission performance measures (Fig. 4). Data packet loss probability as a function of data packet arrival rate λ and probability p, as a function of channel failure rates $\gamma_1 = \gamma_2$ have shown in Fig. 4, 5.

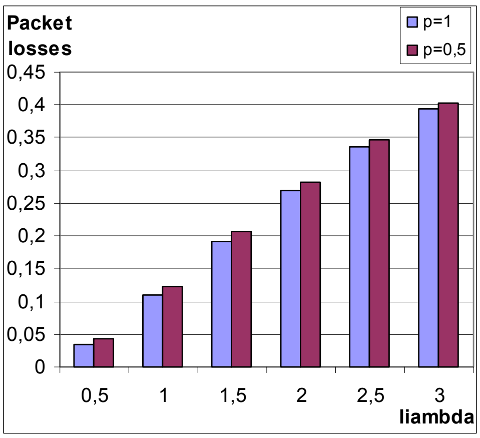

Fig. 4. Packet loss probability as a function of λ and p for the same channels repair and failure rates: $\gamma_1 = \gamma_2$=0.0000115 (corresponds live time 24 hours); $r_1 = r_2$=0.0016 (corresponds repair duration 10 minutes); μ_1=2, μ_2=1

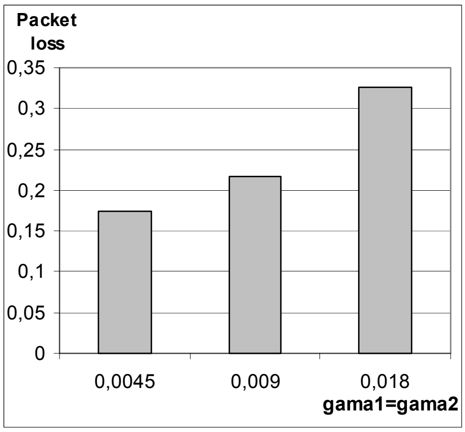

Fig. 5. Packet loss probability as a function of channels failure rates: $\gamma_1 = \gamma_2$ for λ=1.5; $r_1 = r_2$=0.0016; p= 0.5; μ_1=2; μ_2=1

An analytical model was created using only a Poisson distribution (Fig. 4, 5), whereas a simulation model enables to model the various data flows and to model their servicing strategy selecting the wanted probabilistic distribution (for example Pareto, Lognormal, Weibull, Uniform, and others) (Fig. 6).

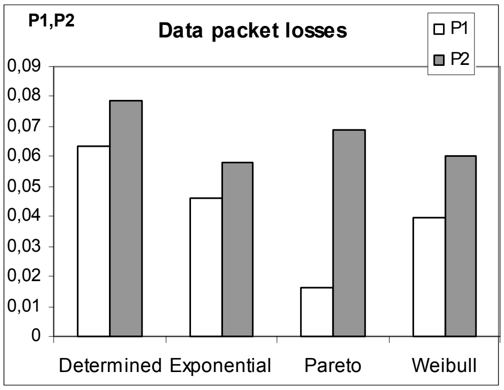

Fig. 6. Packet loss probability, when packet arrival times are distributed by various distributions, when the system intensity $q = 0.64 \div 0.68$, the data transmitting times in channels are exponential with μ_1=2, μ_2=1, the repairing parameters $\mu_i\left(i = \overline{1,4}\right)$= 2, 3, 1, 3; $K = 7$

Conclusions

The system analytical models are accurate only in case of Poisson traffic and exponential data packet transmission time. An exact analytical model becomes complicated when the system has a buffer and size of buffer is large. More general study of system performance measures may be achieved via simulation.

Different strategies used in data network nodes for data packets transmission require new analytical and simulation models for estimating such network performance measures.

A closed simulating system was created to simulate the telecommunication system. Such solution of the task has let to unify the creation of surjections that define the system working.

The data packet flows in telecommunication systems are not only exponential; therefore it's not enough to have only an analytical system model. So the proposed new simulation method – the convolution of Moore and Mealy automata – enables us to simulate various flows for systems.

The simulation results showed that using the various distributions for input flows (when the parameters of distributions for input data flow and packet servicing had taken the same) the numerical characteristics are different.

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A. Žvironienė, Z. Navickas, R. Rindzevičius. Performance Analysis of Unreliable Internet Node // Electronics and Electronical Engineering. – Kaunas: Technologija, 2007. – No. 6(78). – P. 51 – 56.

In this article we propose an analysis of the Internet network node, which is using for transmission two unreliable channels with different bit transmission rates. For system with data packet losses the inter arrival time of data packets flow and the transmission times of each channel are exponentially distributed. Heterogeneous transmission channels often occur in the data network when channels are working in parallel. Research is in progress to develop the analytical and simulation models for such data packets transmission system with unreliable channels. Using our proposed analytical model we can easily evaluate asymmetric unreliable data node with packet losses some performance measures. The simulation model was created using the convolution of Moore and Mealy automata. Proposed simulation model is more common than analytical model, because the inter arrival time of data packets and the transmission times of channels can be distributed by various probabilistic distributions. Moreover the analytical system model was applied only for unreliable network node with data packet losses without queuing, whereas the fixed queues are presented in simulation model. Some performance measures results taken by means of analytical and simulation models are presented in figures. Ill. 6, bibl. 8 (in English; summaries in English, Russian and Lithuanian).

А. Жвиронене, З. Навицкас, Р. Риндзявичюс. Исследование ненадежного узла передачи данных в сети интернета // Электроника и электротехника. – Каунас: Технология, 2007. – № 6 (78). – P. 51 – 56.

Предложена аналитическая модель исследования производительности узла интернета для передачи данных, когда исползуются два ненадежных канала с различной скоростью передачи. Для системы с потерями время между потоками данных во входящем потоке и время передачи по каждому из каналов экспоненнтно распределено. Каналы с различной скоростью передачи данных при их параллельной работе очень часто используются в узлах передачи данных. При исследовании системы созданы не только аналитическая, но и имитационная модели для анализа систем передачи данных. На основе аналитической модели были оценены параметры передачи асимметрической ненадежной системы с потерями. На основе автоматов Миля и Мура создана имитационная модель для анализа ненадежной сети с ожиданием. Предложена имитационная модель является более общей, чем аналитическая, так как в первой модели временные промежутки поступления заявок и их обслуживания могут быть распределены по любому вероятностному закону. Кроме того, в имитационной модели также рассматриваются очереди заявок. Некоторые результаты исследования системы представлены в графиках. Ил. 6, библ. 8 (на английском языке; рефераты на английском, русском и литовском яз.).

A. Žvironienė, Z. Navickas, R. Rindzevičius. Nepatikimo interneto tinklo mazgo veikimo analizė // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 6 (78). – P. 51 – 56.

Pasiūlytas interneto tinklo mazgo (sistemos su duomenų paketų nuostoliais) analizinis modelis, kai naudojami du nepatikimi skirtingos perdavimo spartos kanalai. Kanaluose laikotarpiai tarp paketų atėjimo bei perdavimo trukmės yra pasiskirstę pagal eksponentinį dėsnį. Tinkluose labai dažnai naudojami lygiagrečiai skirtinga sparta veikiantys duomenų perdavimo kanalai. Tyrimo metu sudarytas ne tik analizinis, bet ir imitacinis modeliai, skirti tirti perdavimo sistemoms, naudojančioms nepatikimus duomenų perdavimo kanalus. Remiantis analiziniu modeliu yra įvertinami asimetrinių nepatikimų kanalų mazgo perdavimo parametrai. Imitaciniam modeliui sudaryti buvo panaudoti Milio ir Muro automatų dariniai. Pasiūlytas imitacinis modelis yra bendresnis nei analizinis, nes laikotarpiai tarp paraiškų atėjimo bei aptarnavimo trukmės gali būti pasiskirstę pagal įvairius tikimybinius skirstinius. Be to, analizinis modelis panaudotas tik sistemai su duomenų paketų nuostoliais, o imitaciniame modelyje pateiktos ir fiksuoto ilgio eilės. Kai kurie modelių rezultatai pateikti grafikuose. Il. 6, bibl. 8 (anglų kalba; santraukos lietuvių, anglų ir rusų k.).

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