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DETERMINATION OF PROBABILITY - TEMPORARY CHARACTERISTICS OF COMMUNICATION CHANNELS WHEN TRANSMITTING PRIORITY AND NON-PRIORITY DATA.

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Abstract

The article discusses the issues of finding the main indicators of the quality of the communication channel in computer networks when transmitting priority and non-priority data at different frame lengths. To solve this problem, methods of the theory of queuing using Petri nets are proposed. The proposed method for calculating the temporal and probabilistic characteristics of computer networks allows determinining the main indicators of the quality of the channel in a stationary mode when transmitting priority and non-priority data of computing tools at various values of the input stream intensity. To simulate the transmission of priority and non-priority frames, a color temporary Petri net is proposed. An algorithm is proposed for determining the basic parameters of information transfer, based on the use of the Little formula and allowing one to determine the number of frames in a queue, the average time a frame has been in a queue, and other distinctive features of the algorithm include the use of the window mode. The proposed technique allows to reduce the loss of priority frames of trajectory information and ensuring their transmission in real time.

Key words: *telecommunication protocols, information, frame, transmission, data link layer, messages, efficiency.*

The solution of the problem of finding the probability-time characteristics of a data transmission channel of computer networks is considered. The channel consists of a switch and a communication line connecting it to the information reception and processing center [1-5] and is part of the corporate network. Information frames from transmitting devices arrive at the input port of the switch, and the output port of the channel switch transmits information to the information processing center [6-12]. The specialized channel operates according to the “window transfer with n steps back” algorithm. Priority frames and delayed frames are transmitted through the communication channel according to the same algorithm (with the same average intensity), that is, priorities are not taken into account in the output port of the switch[13-18]. The transmission of frames from the input port to the output is carried out by the switching matrix in a time that is negligible compared to the time of transmission of frames through the communication line [19-21].

The aim of the work is to find the main indicators of the quality of the channel in a stationary mode of operation when transmitting priority and non-priority data of computing tools at various values of the input stream intensity, the length of the "window" and the probability of frame distortion during transmission. These quality indicators when the channel is operating in stationary mode are: the average transmission time of the information frame, the variance of this time, the average number of frames in the system, the average time the frame spent in the system, the average number of frames in the queue, the average time the frame spent in the queue, defined for priority and non-priority frames [22-24].

Theoretical part. Frames transmitted from servers have a length equal to one conventional unit. The transmitter has the right to send in a row without acknowledgment of n frames. The receiver, having received a distorted frame, sends to the transmitter a receipt of a relatively small size δ. In it, he indicates the number of the distorted frame, which must be retransmitted. At the same time, frames following the distorted one (no more than n) should be transmitted in a row, even if they were previously transmitted without errors.

Receipts can be transmitted in the same channel or added to the frames of the reverse stream. If the frames of the return stream are long enough, this introduces an additional delay in the total transmission time of the frame.

The maximum waiting time for confirmation of the correct transmission before the start of retransmission is equal to A frame (Figure 1).

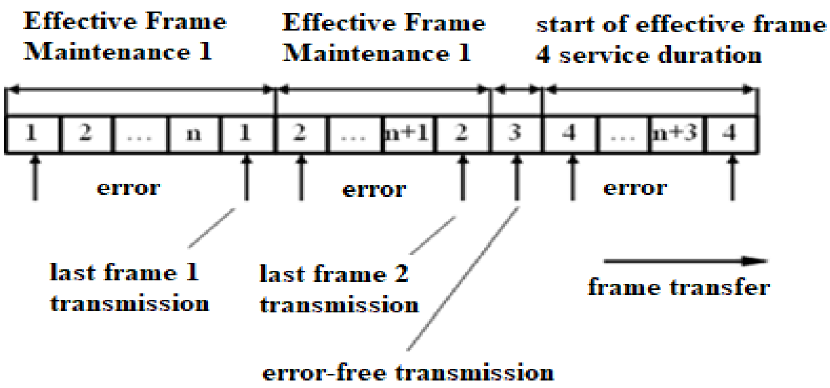

Fig. 1. Effective Durations

If q is the probability of an error-free transmission of a frame, then frame i may be discarded by the receiver with probability $1-q=p$ due to errors. Then the transmitter will transmit the available frames $i=i+2$, $i+2\ldots,i+n-1$, and then frame $i+n$ will be retransmitted. This means that the time interval between the beginning of the first transmission of the frame and the end of the transmission of this frame, taking into account the unit of time δ for the receipt transmission, is equal to $1+\delta+k(n+\delta)$ units of time with probability qp^k (which corresponds to k retransmissions). Then the transmission queue has a service time distribution $P\{X=1+\delta+k(n+\delta)\}=qp^k. \quad k=0,1\ldots n$

The first two moments of service time $\overline{X}$ and $\overline{X^2}$ are found by the formulas:

$$\overline{X}=\sum_{k=0}^{\infty}[1+\delta+k(n+\delta)]qp^k=q\left[(1+\delta)\sum_{k=0}^{\infty}p^k+(n+\delta)\sum_{k=0}^{\infty}kp^k\right],$$

$$\overline{X^2}=\sum_{k=0}^{\infty}[1+\delta+k(n+\delta)]^2qp^k=q\left[(1+\delta)^2\sum_{k=0}^{\infty}p^k+2(1+\delta)(n+\delta)\sum_{k=0}^{\infty}kp^k+(n+\delta)^2\sum_{k=0}^{\infty}k^2p^k\right].$$

Given, that

$$\sum_{k=0}^{\infty}p^k=\frac{1}{q},\ \sum_{k=0}^{\infty}k^2p^k=\frac{p}{q^2},\ \sum_{k=0}^{\infty}k^2p^k=\frac{p+p^2}{q^3}\text{, we get } \overline{X}=1+\frac{\delta+np}{q}, \quad (1)$$

$$\overline{X^2} = (1+\delta)^2 + 2(1+\delta)(n+\delta)\frac{p}{q} + (n+\delta)^2 \frac{p+p^2}{q^2} \quad (2)$$

The value of δ must be taken into account when the ratio of the frame length to the length of the receipt is such that parameter δ affects the accuracy of the calculations, or when the receipts are transmitted in the oncoming stream as part of sufficiently long frames. Most often, the value of δ can be neglected, since the length of the receipt is only a few bytes and is negligible compared to the frame length of the optoelectronic information. The value of δ can also be neglected when the receipt is transmitted in the reverse parallel flow in frames of relatively short length.

The value of $\varepsilon = q + np$ must be interpreted as a mixture of random variables: q - the probability of successful transmission of the frame on the first try and np-probability n of repeated unsuccessful attempts. Let $\delta = 0$, then

$$\overline{X} = 1 + \frac{np}{q} = \frac{\varepsilon}{q} \quad (3)$$

$$\overline{X^2} = \frac{\varepsilon^2 + n^2 p}{q^2} \quad (4)$$

In further calculations, we will use formulas (3) and (4). But if necessary, to calculate the moments of transmission time of the frame through the communication channel, you can use instead of them the expression (1) and (2).

Let's consider two modes of priority transmission of frames.

1. Data transmission channel of optoelectronic devices with priority without interruption of service.

Let $\overline{N_Q^k}$, $k = 1,2$ denote the average number of requirements in the queue of the k th priority; across

$$\rho_k = \frac{\lambda_k}{\mu_k} = \lambda_k \overline{X}, \quad k = 1,2$$

System load for k - th priority. The total system load in stationary mode is less than unity, i.e., $\rho_1 + \rho_2 < 1$. The average delays $\overline{W_1}$ - frames of the highest priority and $\overline{W_2}$ frames of the delayed transmission mode are found for the queuing system M / G / 1 [3-4] according to the formulas:

$$\overline{W_1} = \frac{(\lambda_1 + \lambda_2)\overline{X^2}}{2(1-\lambda_1 \overline{X})} = \frac{(\lambda_1 + \lambda_2)(\varepsilon^2 + n^2 p)}{2q(q - \lambda_1 \varepsilon)}$$

$$\overline{W_2} = \frac{(\lambda_1 + \lambda_2)\overline{X^2}}{2(1-\lambda_1 \overline{X})(1 - \lambda_1 \overline{X} - \lambda_2 \overline{X})} = \frac{\lambda(\varepsilon^2 + n^2 p)}{2(q - \lambda_1 \varepsilon)(q - \lambda\varepsilon)}$$

Average delay of requirement k - priority $\overline{T_k} = \overline{X} + \overline{W}_k$, $k = 1,2$. For priority frames

$$\overline{T_1} = \frac{\varepsilon}{q} + \frac{(\lambda_1 + \lambda_2)(\varepsilon^2 + n^2 p)}{2q(q - \lambda_1 \varepsilon)},$$

and for delayed frames

$$\overline{T}_2 = \frac{\varepsilon}{q} + \frac{\lambda\left(\varepsilon^2 + n^2 p\right)}{2(q - \lambda_1\varepsilon)(q - \lambda\varepsilon)}.$$

Little's formula

$$\overline{N_Q^k}, = \lambda_k \overline{W_k},\ k = 1{,}2$$

we get the expressions N_Q^1 for the average number of priority frames in the channel queue and N_Q^2 - the average number of frames in the queue transmitted in deferred mode

$$\overline{N}_Q^1 = \frac{\lambda_1(\lambda_1 + \lambda_2)\left(\varepsilon^2 + n^2 p\right)}{2q(q - \lambda_1\varepsilon)},$$

$$\overline{N}_Q^2 = \frac{\lambda_2\lambda\left(\varepsilon^2 + n^2 p\right)}{2(q - \lambda_1\varepsilon)(q - \lambda\varepsilon)}.$$

The expressions for N_1 are the average number of priority frames in the system and for N_2 the average number of frames in the system transmitted in deferred mode, we find using the Little formula:

$$\overline{N}_k = \lambda_k \overline{T}_k\ , k = 1{,}2;\ \overline{N}_1 = \frac{\varepsilon\lambda_1}{q} + \frac{\lambda_1(\lambda_1 + \lambda_2)\left(\varepsilon^2 + n^2 p\right)}{2q(q - \lambda_1\varepsilon)},\ \overline{N}_2 = \frac{\lambda_2\varepsilon}{q} + \frac{\lambda_2\lambda\left(\varepsilon^2 + n^2 p\right)}{2(q - \lambda_1\varepsilon)(q - \lambda\varepsilon)}.$$

Optical-electronic data transmission channel with priority with interruption and after-service.

The average value of the duration of stay in the system of priority frames [5,6] is determined by the formula:

$$\overline{T}_1 = \frac{2\varepsilon(q - \lambda_1\varepsilon) + \lambda_1\left(\varepsilon^2 + n^2 p\right)}{2q(q - \lambda_1\varepsilon)}, \tag{5}$$

and the average value of the duration of stay in the system of frames transmitted in deferred mode:

$$\overline{T}_2 = \frac{2\varepsilon(q - \lambda\varepsilon) + \lambda\left(\varepsilon^2 + n^2 p\right)}{2(q - \lambda_1\varepsilon)(q - \lambda\varepsilon)}. \tag{6}$$

The corresponding values of the average time spent in the input queue for priority and non-priority channel frames are determined by the expressions:

$$\overline{W}_1 = \frac{\lambda_1\left(\varepsilon^2 + n^2 p\right)}{2q(q - \lambda_1\varepsilon)}, \tag{7}$$

$$\overline{W}_2 = \frac{\lambda\left(\varepsilon^2 + n^2 p\right)}{2(q - \lambda_1\varepsilon)(q - \lambda\varepsilon)} + \frac{\lambda_1\varepsilon^2}{q(q - \lambda_1\varepsilon)}. \tag{8}$$

Using Little's formulas, we find the average values:

- the number of priority frames in the queue

$$\overline{N}_Q^1 = \lambda_1 \overline{W}_1;$$

- the number of frames in the queue transmitted in deferred mode,

$$\overline{N}_Q^2 = \lambda_2 \overline{W}_2;$$

- the number of priority frames in the system

$$\overline{N}_1 = \lambda_1 \overline{T}_1;$$

- the number of frames in the system transmitted in deferred mode,

$$\overline{N}_2 = \lambda_2 \overline{T}_2.$$

Substituting the corresponding values from formulas (5-8) into these expressions, we obtain:

We verify the results obtained using an example

$$\overline{N}_Q^1 = \frac{\lambda_1^2\left(\varepsilon^2 + n^2 p\right)}{2q\left(q - \lambda_1\varepsilon\right)},$$

$$\overline{N}_Q^2 = \lambda_2\left\{\frac{\lambda_1\varepsilon^2}{q\left(q - \lambda_1\varepsilon\right)} + \frac{\lambda\left(\varepsilon^2 + n^2 p\right)}{2\left(q - \lambda_1\varepsilon\right)\left(q - \lambda\varepsilon\right)}\right\},$$

$$\overline{N}_1 = \frac{\varepsilon\lambda_1}{q} + \frac{\lambda_1^2\left(\varepsilon^2 + n^2 p\right)}{2q\left(q - \lambda_1\varepsilon\right)},$$

$$\overline{N}_2 = \frac{\lambda_2}{q - \lambda_1\varepsilon}\left\{\varepsilon + \frac{\lambda\left(\varepsilon^2 + n^2 p\right)}{2\left(q - \lambda\varepsilon\right)}\right\},$$

Let it exist (a system with priority without interruption of service).

Since the system should operate in a stationary mode at load $\rho = \lambda\overline{X} < 1$, we accept $\lambda = 0{,}4$. Typical window lengths $n = 4{,}8$ were taken. The calculation results for $n = 8$ are shown in table 1. Based on the calculation results, the following conclusions can be made. When the probability of a frame $\rho = 0{,}01$ failure, a decrease in the window length from $n = 8$ to $n = 4$ leads to a decrease in the average packet transmission time from 1.08 to 1.04, i.e., by about 4%, which is in good agreement with the fact that in practice when channel receiver is overloaded it is recommended reduce the size of the window.

The priority of real-time frames determines a higher quality of their service in comparison with the quality of service of personnel in deferred mode.

This is especially noticeable with relatively high probabilities of frame distortion in the communication channel. In particular, with $\rho = 0{,}05$ and $n = 8$, the average waiting time is for priority packets in queue $\overline{W}_1 = 1{,}56$, and for non-priority packets $\overline{W}_2 = 3{,}60$ (a difference of 2.32 times). But when reducing the probability of a frame failure to 0.01, the average values of the residence time are equal to $\overline{W}_1 = 0{,}47$ and $\overline{W}_2 = 0{,}82$; the ratio between these values decreases to 1.76. This is because, with a decrease in the probability of error ρ, priority frames are delayed less and less in the input queue of the channel, creating the prerequisites for reducing the time spent in the queue of frames of delayed time.

Table. 1.

Calculation results

Parameter	For frames with priority		For time delay frames	
	ρ		ρ	
	0,05	0,01	0,05	0,01
$\overline{X}$	1,42	1,08	1,42	1,08
$\overline{X^2}$	5,57	1,82	5,56	1,82

δ^2	3,55	0,65	3,55	0,65
3δ	5,65	2,42	5,65	2,42
$\overline{W}$	1,56	0,47	3,60	0,82
$\overline{T}$	2,90	1,54	5,02	1,90
$\overline{N}$	0,60	0,31	1,01	0,38

Table 2 allows you to compare the results of calculations of the main parameters of the data transmission channel of optoelectronic devices (path information) in the operating mode with absolute and relative priorities ($n = 8$, $\rho = 0{,}01$, $\lambda = 0{,}4$).

Absolute priority real-time frames are faster transmitted and less delayed in queues, since they compete only with each other. Frames of delayed mode are transmitted with relative priority better than with absolute priority, since in this case their processing in the channel is not interrupted.

Table. 2.

Channel Options

Parameter	Real time frames		Deferred frames	
	Abs.prior	prior.	Abs.prior	prior.
$\overline{T}$	1,31	1,54	2,2	1,9
$\overline{W}$	0,23	0,47	1,12	0,82
$\overline{N}$	0,26	0,31	0,44	0,28

Thus, the proposed methodology for calculating the probabilistic-temporal characteristics of a windowed data transmission channel, provided that a Poisson data stream from several calculated complexes is fed to the channel input, the channel operates in a stationary mode.

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