



THE ISSUE CONTAINS:

Proceedings of the 4th
International Scientific
and Practical Conference

**RECENT ADVANCES
IN GLOBAL SCIENCE**

Vilnius, Lithuania
6-8.05.2024

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RADIO ENGINEERING, ELECTRONICS AND ELECTRICAL ENGINEERING

Determination of the analytical expression for the probability density of time delays in the network

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The success of the development of various industries is directly related to the introduction of telecommunication technologies into them. At the same time, it becomes possible to create distributed control systems where the operator is located at a considerable distance from the control object. The efficiency of automatic control systems in case of a significant distance of a control object is related to the time delay in data transmission generated by the nodes of the network [1]. The presence of delays often affects the performance of the system, and it is not always possible to eliminate delays by purely technical means [2]. In this case, the need to theoretically estimate and predict delays, as well as determine their impact on the stability of the system, becomes important. The data transmission time delays can be considered as a random variables with an unknown distribution law in advance [3].

The purpose of the research is to determine on the basis of experimental data the distribution law of data transmission time delays over the network and obtain an analytical expression describing the empirical probability density.

The time delay of a signal along its path from the sender to the recipient consists of several parts: processing time at each node, transmission time, and signal propagation time. Each of these stages may vary in duration, determined by the technical condition of the network, and various uncontrollable random reasons. In this regard, the time delay

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τ is considered a continuous random variable with a certain distribution law. Statistical methods of analysis make it possible to empirically construct a distribution curve for a given random variable. Once it is plotted, the approximate time delay can be found as the area under the distribution curve in a given range. As a rule, the empirical construction of a distribution curve occurs as follows. A series of experiments is carried out to determine the delay and continuous variation series are constructed.

A series of tests were carried out with a volume of 500 samples in each of them. These tests are summarized as an average variation series and are presented in Table 1, where n_i – frequency, n – sample size, h – range.

Table 1

Summary of test results			
i	$\tau_i - \tau_{i+1}$	n_i	$\frac{n_i}{n \cdot h}$
1	21 ÷ 23	264	0.264
2	23 ÷ 25	185	0.185
3	25 ÷ 27	25	0.025
4	27 ÷ 29	11	0.011
5	29 ÷ 31	4	0.004
6	31 ÷ 33	3	0.003

The main numerical characteristics were found: mode $M_0 \approx 22$; median $M_e \approx 27$; average $\bar{\tau} = 27$; dispersion $S^2 = 16.824$; standard deviation $S = 4.102$; coefficient of variation $V = 62.3\%$. In Fig. 1 is a histogram of relative frequencies, which shows the empirical probability density.

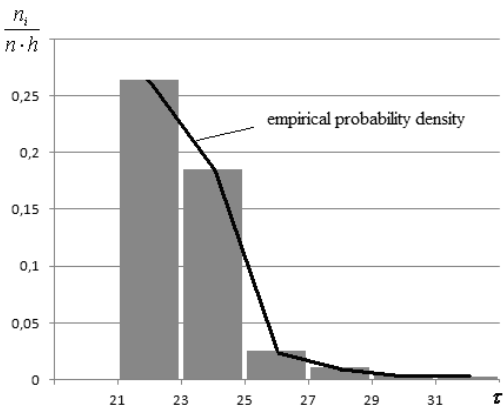


Figure 1
Histogram of relative frequencies

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Based on the shape of the empirical distribution curve, we look for the theoretical probability density in the form:

$$f(\tau) = ae^{b\tau}.$$

After processing the received data, the desired delay probability density can be written as:

$$f(\tau) = 15240 \cdot e^{-0.495\tau}.$$

Comparing the time delays determined by this formula with the experimental ones, one can note their satisfactory agreement.

The first stage of the analysis included studying the nature of time delays in the network, which is key to properly understanding the problem. The second stage involved a statistical analysis of these delays and determination of their distribution law. The results obtained can be used to build models of remote control systems that take into account the influence of real delays that occur in the control loop. In turn, this will make it possible to optimize the coefficients of PID controllers and significantly reduce the negative impact of time delays on the quality of control. This approach allows to solve problems associated with small delays in the Internet effectively, which can affect the operation of control systems for electronic equipment.

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