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CALCULATION OF THE EFFECTIVENESS OF THE FUNCTIONING OF MULTISERVICE COMMUNICATION NETWORKS TAKING INTO ACCOUNT DROPPED PACKETS

Gulrukh Bakhtiyorovna Sherboboyeva
doctor of philosophy on technical sciences, Karshi branch of TUIT named after Muhammad al-Khwarizmi

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Sherboboyeva Gulrukh Bakhtiyorovna
doctor of philosophy on technical sciences,
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Abstract:

Background. *The article discusses the formalization of performance indicators of a multiservice network management system based on the use of hybrid neural-fuzzy technology that combines the advantages of fuzzy logic and neural networks. A developed fuzzy neural model was subsequently used to make a decision about the transfer of real time streams through the channel of the multi-servo network. Methods for assessing the effectiveness of multiservice communication networks can be conditionally divided into three large groups: technical, economic and technical and economic. As the technical characteristics of the efficiency of the computer network, various indicators of network performance and reliability are used. Estimates of the costs of designing, installing and maintaining the network are used as economic characteristics. Technical and economic indicators are used for a comprehensive assessment of the project, and include various combinations of technical and economic characteristics. The response time is an integral performance characteristic, the most important for the network subscriber. In general, the response time is defined as the time interval between the occurrence of a subscriber's request for a network service and the receipt of a response to this request.*

Methods. *When implementing in the channel dynamic redistribution of the bandwidth allocated for the transmission of packets of various classes, the model of neuro-fuzzy prediction of the number of dropped packets proposed. The number of discarded packets of a given class from the number that claimed to be transmitted over the channel depends, firstly, on the dynamics of the arrival of packets of this class for transmission over the channel and, secondly, on what the current value of the channel bandwidth is allocated for the transmission of these packets.*

Studies have shown that to predict the number of packets of a given class, it is advisable to supply data on the number of received packets in the three previous cycles (values of Z_a, Z_b *and* Z_c*) to the input of a fuzzy neural system, as well as the value* V_d *- the value of the channel bandwidth allocated in the current cycle for transmitting packets of this class over a telecommunication network channel.*

Findings. *This decrease in the allocated bandwidth led to the fact that against the background of the increase in the number of received packets* Z_i *observed in cycles 8 and 9 (see Figure 7), the number of dropped packets in cycle 9 increased compared to cycle 4 (*$R_9 > R_4$*). The analysis presented in Figure 8 and Figure 9 of the results shows that the predicted value of* $\check{R}_i$*,*

which is calculated by the neuro-fuzzy system in each current cycle i, practically coincides with the real values of the number of dropped packets R_i recorded in the next cycle (i + 1). The prediction accuracy, established as a result of numerous simulation experiments, is 95–97 %.

Conclusions. *To compare the results obtained with the same initial data, a series of simulation experiments was carried out using a model in which the choice of an intersegment interval was implemented based on the use of a fuzzy inference system. The results of the experiments are presented in graphs showing the dependence of the duration of the data flow and the loss of segments on the average available bandwidth of the telecommunication channel. On these graphs, solid curves show the characteristics of the data stream transmission obtained using neuro-fuzzy selection of the inter-segment interval, and the dashed curves show the results of the management of the inter-segment interval based on the application of the system. The analysis of the presented dependencies shows that when transmitting a data stream over a channel, the available bandwidth of which does not exceed 50 %, the use of a neuro-fuzzy system to select an inter-segment interval provides a decrease in segment losses by 5.2–11.3 % and a decrease in the average time of streaming data by 7.1-12.3 %.*

Thus, a neuro-fuzzy model has been developed, designed to select the inter-segment interval in a telecommunications network. Unlike the existing ones, this model is based on the use of a fuzzy neural network apparatus. The results of simulation showed that the use of the developed model of the shortage of available channel capacity will ensure a decrease in segment losses and a decrease in the average transmission time of data streams.

Keywords: *fuzzy logic, neural networks, hybrid, term, fuzzification, multiservice network, neural-fuzzy technology, inter-segment interval, defuzzification.*

Introduction. The modern stage of informatization of society is characterized by the widespread introduction of multi-level multiservice systems with the integration of infocommunication services into various fields of activity. This is due to the fact that integrated-level multiservice systems allow direct communication with users. In addition, multiservice communication networks, unlike traditional networks, provide a wide range of services instead of one service.

On the other hand, a multiservice communication network is a very complex multicomponent object, which is characterized by various properties, and it is a universal multipurpose environment designed for voice, image and data transmission using packet switching technology [1]. The main task of multiservice networks is to ensure the operation of heterogeneous information and telecommunication systems and applications in a single transport environment, when a single infrastructure is used to transmit normal traffic (data) and traffic of other information (voice, video, etc.) [2,3]. A multiservice communication network can be used to provide various types of services that differ in the required capacity of the communication channel and the requirements for the quality of data transmission. In modern communication networks, the following parameters are usually distinguished, which affect the quality of data transmission [4].

Latency - the time that data travels over the network. When transmitting voice and video data, there are particularly stringent requirements for the maximum allowable latency. One-way delay should not exceed 100 ms (delay for data transmission and delay for their decoding by the subscriber's equipment). To reduce the delay introduced by the network, use QoS (Quality of Service) - the preference of some transmitted data over others [5].

Jitter - packets in data networks can be received by the client not in the order in which they were sent to him, since different routes with different characteristics of speed and distance could be used to deliver packets. To solve problems of this kind, jitter buffers are used. The purpose of these buffers is to pre-accumulate packets before and further transmission to the decoder.

Packet Loss. The impact of packet loss in data networks on video and voice quality is determined by the packet size and the encoding method used. For normal operation of IP - telephony systems, the loss of 1% of packets is allowed otherwise the speech quality deterioration is noticeable [6].

The quality of the provision of infocommunication services is significantly influenced by the structure of the network, the throughput of communication channels, as well as the discipline of service. An important factor affecting the quality of service in any communication networks is the network efficiency, which in this work is understood as the probability of the network performing its functions qualitatively in the event of a possible failure of network elements.

The specific features of multiservice networks are determined by the following factors:

- multiservice networks consist of a relatively large number of different types of components, while existing networks are characterized by a small number of large and less heterogeneous switching devices;
- multiservice networks support more interfaces and provide higher bandwidth than existing networks;
- unlike existing networks, multiservice networks provide a universal set of solutions to support management processes in networks for various purposes (fixed and mobile telephone networks, data transmission networks, signaling networks, etc.);
- multiservice networks are able to provide and support an unlimited number of types of services (from traditional to new information and telecommunications) with an arbitrary order of increasing the number of applications;
- multiservice networks provide support for equipment management processes from different manufacturers;
- multiservice networks operate in conditions of considerable geographic extent: in a mode close to real time, they provide coordinated performance of control functions for equipment operating in different time zones;
- control systems of multiservice networks, designed for processing and storing control information, have the appropriate productivity resources and the necessary capabilities to create the normal operation of service personnel [7].

It is known that multiservice communication networks are built on the basis of the NGN technology concept of the existing three-layer structure - services / management / transport [8,9].

The network is based on a universal transport network that implements the functions of the transport layer and the control layer of switching and transmission. The transport network may include:

- transit nodes performing the functions of transfer and switching;
- terminal (border) nodes that provide subscribers with access to the multiservice network;
- signaling controllers performing functions of signaling information processing, call and connection control;
- gateways allowing connection of traditional communication networks.

E_{eff} performance indicators depend on a number of important system parameters. The main role among them is played by the high-speed parameters of subscriber and network terminals, the probabilistic-temporal characteristics of telecommunication networks, conditioned by the conditions and methods of using the system and are described by the following functional dependence:

$$E_{eff} = \left\{ E \left\lfloor \max_i (C_{i.m.n}\eta_i) \min (T_{i,mid.z} C_a) \right\rfloor, \ i = \overline{1,n} \right\},$$

where $C_{i.m.n}$ –is the maximum value of the peak throughput of the terminal equipment of multiservice communication networks when transmitting the *i*-th packet stream; $T_{i,cp.з}$ – the average delay time when transmitting the *i*-th packet stream; C_a – the cost of hardware and software for terminal equipment of multiservice communication networks; η_i – the coefficient of efficient use of terminal and network resources required for service during transmission of the *i*-th packet stream. This expression determines the mathematical formulation of the problem for assessing the performance characteristics of the terminal equipment of telecommunication networks when servicing heterogeneous traffic, and it can be called the target efficiency of the system.

To ensure the guaranteed quality of service for the streams of voice packets and video traffic generated by real-time applications, $T_{i.mid}$ $i = i = 1, n$ it is necessary to create conditions so that the delay in the transmission of any traffic is limited to an acceptable value.

Based on the operation algorithm of the network link when transmitting the i-th traffic packet flow from the load source to the receiver, the minimum value of the average delay time is determined by the inequality:

$$T_{i.ave} = Arg\min[T_{i+1}(\lambda_{exit}) - T_i(\lambda_{ent})]K^{-1}_{i.сж} \le T_{i.eff}, \quad 1 \le i \le n$$

where $T_i(\lambda_{ent})$ and $T + 1_i(\lambda_{exit})$ – the times of occurrence of the i – th traffic flow at the BN input of the input port with a speed of λ_{ent} and at the output from the output switch of the network with λ_{exit} respectively; $K_{i.sq}$ – traffic compression ratio of the i-th packet stream based on differential algorithms and algorithms for interpolation of speech and video signals.

Methods to improve the efficiency of multiservice communication networks. A specific feature of a multiservice network, from a management point of view, is that these networks consist of a larger number of different types of components. In addition, a multi-service network assumes the use of a large number of interfaces and higher bandwidth. A modern multiservice system is a complex object of management, characterized by features that must be taken into account during management, therefore, to analyze the processes of managing the system, a systematic approach is used, when multiservice networks are considered as a set of interconnected components that have outputs, goals, inputs and resources, communication with external environment, feedback.

The main and urgent problem of the study of multiservice communication networks is to assess the quality of the terminal equipment functioning, which ensures the guaranteed quality of the services provided.

Combining various types of communication on the basis of modern unified organizational and technological principles is one of the stages in the creation of multi-service communication networks of the next generation NGN (Next Generation Network).

Methods for assessing the effectiveness of multiservice communication networks can be conditionally divided into three large groups: technical, economic and technical and economic. As the technical characteristics of the efficiency of the computer network, various indicators of network performance and reliability are used. Estimates of the costs of designing, installing and maintaining the network are used as economic characteristics. Technical and economic indicators are used for a comprehensive assessment of the project, and include various combinations of technical and economic characteristics. Network performance is assessed using several basic indicators [8,9,10]:

- reaction time;
- throughput;
- mean and variance of the delay.

The response time is an integral performance characteristic, the most important for the network subscriber. In general, the response time is defined as the time interval between the occurrence of a subscriber's request for a network service and the receipt of a response to this request.

The instantaneous throughput differs from the average in that a short time interval is selected for averaging, about 10ms. Maximum throughput is the highest instantaneous throughput recorded during the observation period. When designing networks, average and maximum bandwidths are most often used. Average bandwidth allows you to evaluate the network performance over a long time interval, during which peaks and troughs in traffic intensity compensate each other. Maximum bandwidth allows you to assess the network's ability to handle peak loads.

The transmission delay is defined for any switching device or network segment. The transmission delay is equal to the time interval between the moment a packet arrives at the input of a device or network segment and the moment this packet appears at the output of a device or segment. This parameter is similar to the network response time, but, unlike the latter, it

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characterizes the process of frame transmission over the network, without taking into account the processing time of this frame on the server and on the subscriber's computer. One of the most important characteristics to consider when designing any computer network is the nature and intensity of data traffic. The reliability of a computer network is a complex criterion, and can be characterized by the availability, the probability of packet delivery, and fault tolerance.

Another characteristic of reliability is fault tolerance, that is, the ability of the system to hide the failure of individual segments from the user. In a fault-tolerant system, the failure of an individual element leads to some decrease in the quality of service, but not to a complete shutdown. One of the important indicators of the quality of the functioning of the transmission system paths and routing flows of different types of traffic packets is the maximum value of the peak throughput (Peak-raite throughput), which characterizes the maximum number of packets that a link can transmit per unit time.

When implementing in the channel dynamic redistribution of the bandwidth allocated for the transmission of packets of various classes, the model of neuro-fuzzy prediction of the number of dropped packets proposed in [11] requires improvement. The number of discarded packets of a given class from the number that claimed to be transmitted over the channel depends, firstly, on the dynamics of the arrival of packets of this class for transmission over the channel and, secondly, on what the current value of the channel bandwidth is allocated for the transmission of these packets.

Studies have shown that to predict the number of packets of a given class, it is advisable to supply data on the number of received packets in the three previous cycles (values of Z_a, Z_b and Z_c) to the input of a fuzzy neural system, as well as the value V_d - the value of the channel bandwidth allocated in the current cycle for transmitting packets of this class over a telecommunication network channel.

Results and discussion. The output variable in such a fuzzy neural system is the value $\tilde{R}_e$ - the predicted value of the number of packets of a given class that will be discarded in the current cycle. For each input quantity, it is advisable to use two triangular membership functions. The implementation of a qualitative forecast with such initial data can ensure the use of the 1st order Sugeno fuzzy inference algorithm [12], according to which the base of fuzzy rules is as follows:

$$
\begin{aligned}
&If\ a\ (Z_a=\alpha_1)\ and\ (Z_b=\beta_1)\ and\ (Z_c=\gamma_1)\ and\ (V_d=\delta_1),\ then\ (\tilde{R}_e=Y_1),\\
&If\ a\ (Z_a=\alpha_1)\ and\ (Z_b=\beta_1)\ and\ (Z_c=\gamma_1)\ and\ (V_d=\delta_2),\ then\ (\tilde{R}_e=Y_1),\\
&If\ a\ (Z_a=\alpha_1)\ and\ (Z_b=\beta_1)\ and\ (Z_c=\gamma_2)\ and\ (V_d=\delta_1),\ then\ (\tilde{R}_e=Y_1),\\
&If\ a\ (Z_a=\alpha_1)\ and\ (Z_b=\beta_1)\ and\ (Z_c=\gamma_2)\ and\ (V_d=\delta_2),\ then\ (\tilde{R}_e=Y_1),\\
&If\ a\ (Z_a=\alpha_1)\ and\ (Z_b=\beta_2)\ and\ (Z_c=\gamma_1)\ and\ (V_d=\delta_1),\ then\ (\tilde{R}_e=Y_1),\\
&If\ a\ (Z_a=\alpha_1)\ and\ (Z_b=\beta_2)\ and\ (Z_c=\gamma_1)\ and\ (V_d=\delta_2),\ then\ (\tilde{R}_e=Y_1),\\
&If\ a\ (Z_a=\alpha_1)\ and\ (Z_b=\beta_2)\ and\ (Z_c=\gamma_2)\ and\ (V_d=\delta_1),\ then\ (\tilde{R}_e=Y_1),\\
&If\ a\ (Z_a=\alpha_1)\ and\ (Z_b=\beta_2)\ and\ (Z_c=\gamma_2)\ and\ (V_d=\delta_2),\ then\ (\tilde{R}_e=Y_1),\\
&If\ a\ (Z_a=\alpha_2)\ and\ (Z_b=\beta_1)\ and\ (Z_c=\gamma_1)\ and\ (V_d=\delta_1),\ then\ (\tilde{R}_e=Y_1)\ ,\\
&If\ a\ (Z_a=\alpha_{21})\ and\ (Z_b=\beta_1)\ and\ (Z_c=\gamma_1)\ and\ (V_d=\delta_2),\ then\ (\tilde{R}_e=Y_1)\ ,\\
&If\ a\ (Z_a=\alpha_2)\ and\ (Z_b=\beta_1)\ and\ (Z_c=\gamma_2)\ and\ (V_d=\delta_1),\ then\ (\tilde{R}_e=Y_1)\ ,\\
&If\ a\ (Z_a=\alpha_2)\ and\ (Z_b=\beta_1)\ and\ (Z_c=\gamma_2)\ and\ (V_d=\delta_2),\ then\ (\tilde{R}_e=Y_1)\ ,\\
&If\ a\ (Z_a=\alpha_2)\ and\ (Z_b=\beta_2)\ and\ (Z_c=\gamma_1)\ and\ (V_d=\delta_1),\ then\ (\tilde{R}_e=Y_1)\ ,\\
&If\ a\ (Z_a=\alpha_2)\ and\ (Z_b=\beta_2)\ and\ (Z_c=\gamma_1)\ and\ (V_d=\delta_2),\ then\ (\tilde{R}_e=Y_1)\ ,\\
&If\ a\ (Z_a=\alpha_2)\ and\ (Z_b=\beta_2)\ and\ (Z_c=\gamma_2)\ and\ (V_d=\delta_1),\ then\ (\tilde{R}_e=Y_1)\ .
\end{aligned}
\quad (1)
$$

where α_1- term number 1 of the input value Z_a; α_1- term number 2 of the input quantity Z_a; β_1- term number 1 of the input quantity Z_b; β_2- term number 2 of the input quantity Z_b; γ_1- term number 1 of the input value Z_c; γ_2- term number 2 of the input value Z_c; δ_1 - term number 1 of the input quantity V_d; δ_2 -term number 2 of the input value V_d; $Y_1, Y_2,...., Y_{16}$- values of individual conclusions of fuzzy rules. Types and parameters of membership functions for each input quantity are shown in Figure. 1-4.

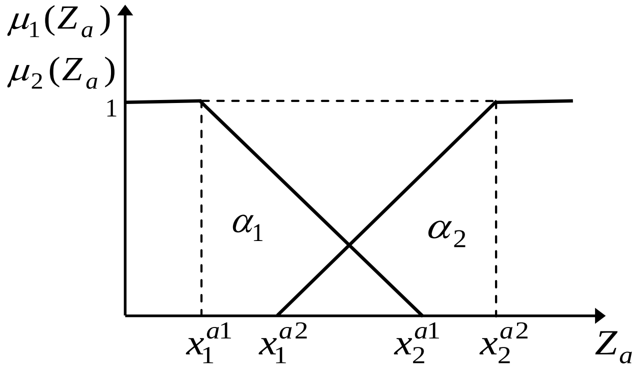

Figure 1. The type and parameters of the membership functions of the input quantity Z_a

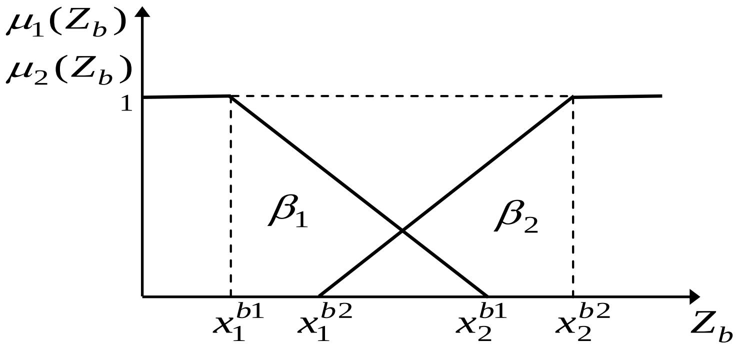

Figure 2. The type and parameters of the membership functions of the input quantity Z_b

In accordance with the specified algorithm, the values of individual conclusions of fuzzy rules are determined using the expression:

$$Y_r = y_1^r Z_a + y_2^r Z_b + y_3^r Z_c + y_4^r Z_d + y_5^r, \ (2)$$

where $y_1^r, +y_2^r,...., y_5^r$ are the coefficients for calculating the individual output of the fuzzy rule number r.

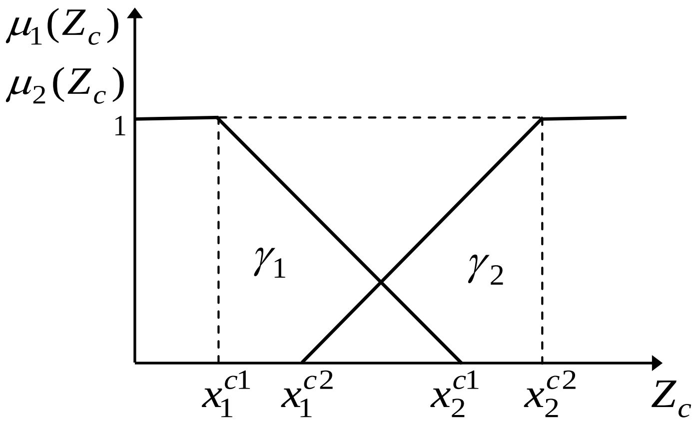

Figure 3. The type and parameters of the membership functions of the input quantity Z_c

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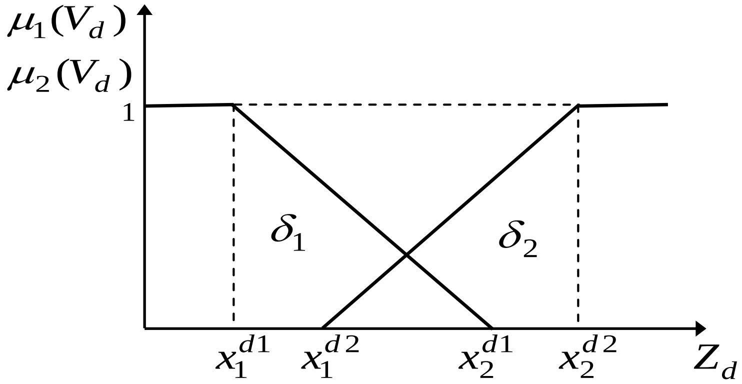

Figure 4. The type and parameters of the membership functions of the input quantity V_d

The synthesized neuro-fuzzy system consists of five layers (Figure 5).

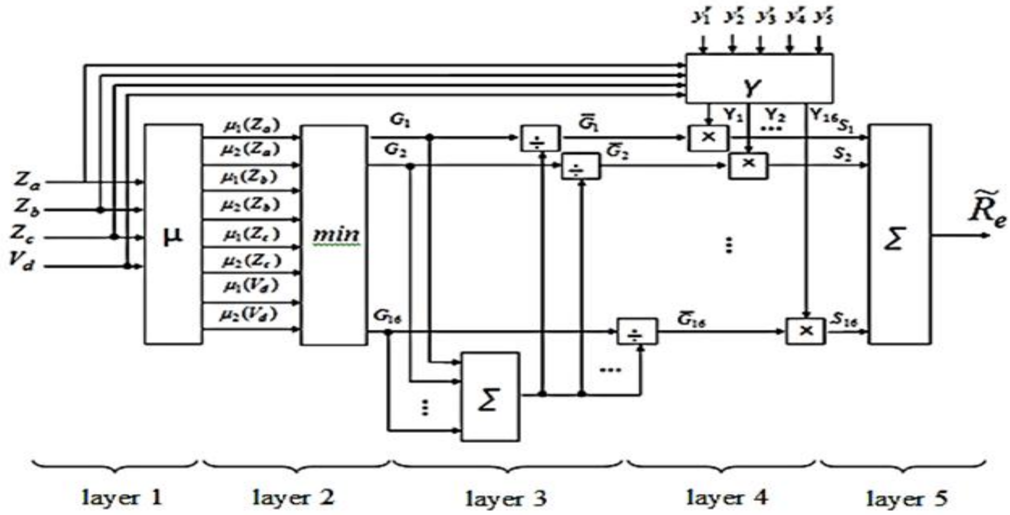

Figure 5. Neural fuzzy network structure

The first layer of neurons performs the fuzzification procedure, i.e. calculates the values of the membership functions for each input value:

$$\mu_1(Z_a)=\begin{cases}1, & Z_a<x_1^{a1};\\ \dfrac{x_2^{a1}-Z_a}{x_2^{a1}-x_1^{a1}}, & x_1^{a1}\le Z_a<x_2^{a1};\\ 0, & Z_a\ge x_2^{a1};\end{cases}\qquad \mu_2(Z_a)=\begin{cases}0, & Z_a<x_1^{a2};\\ \dfrac{Z_a-x_1^{a2}}{x_2^{a2}-x_1^{a2}}, & x_1^{a2}\le Z_a<x_2^{a2};\\ 1, & Z_a\ge x_2^{a2};\end{cases}$$

$$\mu_1(Z_b)=\begin{cases}1, & Z_b<x_1^{b1};\\ \dfrac{x_2^{b1}-Z_b}{x_2^{b1}-x_1^{b1}}, & x_1^{b1}\le Z_b<x_2^{b1};\\ 0, & Z_b\ge x_2^{b1};\end{cases}\qquad \mu_2(Z_b)=\begin{cases}0, & Z_b<x_1^{b2};\\ \dfrac{Z_b-x_1^{b2}}{x_2^{b2}-x_1^{b2}}, & x_1^{b2}\le Z_b<x_2^{b2};\\ 1, & Z_b\ge x_2^{b2};\end{cases} \quad (3)$$

$$\mu_1(Z_c)=\begin{cases}1, & Z_c<x_1^{c1};\\ \dfrac{x_2^{c1}-Z_c}{x_2^{c1}-x_1^{c1}}, & x_1^{c1}\le Z_c<x_2^{c1};\\ 0, & Z_c\ge x_2^{c1};\end{cases}\qquad \mu_2(Z_c)=\begin{cases}0, & Z_c<x_1^{c2};\\ \dfrac{Z_c-x_1^{c2}}{x_2^{c2}-x_1^{c2}}, & x_1^{c2}\le Z_c<x_2^{c2};\\ 1, & Z_c\ge x_2^{c2};\end{cases}$$

$$\mu_1(V_d)=\begin{cases}1, & V_d < x_1^{v1};\\ \dfrac{x_2^{v1}-V_d}{x_2^{v1}-x_1^{v1}}, & x_1^{v1}\le V_d < x_2^{v1};\\ 0, & V_d \ge x_2^{v1};\end{cases} \qquad \mu_2(V_d)=\begin{cases}0, & V_d < x_1^{v2};\\ \dfrac{V_d-x_1^{v2}}{x_2^{v2}-x_1^{v2}}, & x_1^{v1}\le V_d < x_2^{v2};\\ 1, & V_d \ge x_2^{v2}.\end{cases}$$

The second layer of neurons carries out the aggregation procedure, as a result of which the degrees of truth of each fuzzy rule are determined:

$$\begin{aligned}
&G_1=\mu_1(Z_a)\wedge\mu_1(Z_b)\wedge\mu_1(Z_c)\wedge\mu_1(V_d);\; G_2=\mu_1(Z_a)\wedge\mu_1(Z_b)\wedge\mu_1(Z_c)\wedge\mu_2(V_d);\\
&G_3=\mu_1(Z_a)\wedge\mu_1(Z_b)\wedge\mu_2(Z_c)\wedge\mu_1(V_d);\; G_4=\mu_1(Z_a)\wedge\mu_1(Z_b)\wedge\mu_2(Z_c)\wedge\mu_2(V_d);\\
&G_5=\mu_1(Z_a)\wedge\mu_2(Z_b)\wedge\mu_1(Z_c)\wedge\mu_1(V_d);\; G_6=\mu_1(Z_a)\wedge\mu_2(Z_b)\wedge\mu_1(Z_c)\wedge\mu_2(V_d);\\
&G_7=\mu_1(Z_a)\wedge\mu_2(Z_b)\wedge\mu_2(Z_c)\wedge\mu_1(V_d);\; G_8=\mu_1(Z_a)\wedge\mu_2(Z_b)\wedge\mu_2(Z_c)\wedge\mu_2(V_d);\\
&G_9=\mu_2(Z_a)\wedge\mu_1(Z_b)\wedge\mu_1(Z_c)\wedge\mu_1(V_d);\; G_{10}=\mu_2(Z_a)\wedge\mu_1(Z_b)\wedge\mu_1(Z_c)\wedge\mu_2(V_d);\quad (4)\\
&G_{11}=\mu_2(Z_a)\wedge\mu_1(Z_b)\wedge\mu_2(Z_c)\wedge\mu_1(V_d);\; G_{12}=\mu_2(Z_a)\wedge\mu_1(Z_b)\wedge\mu_2(Z_c)\wedge\mu_2(V_d);\\
&G_{13}=\mu_2(Z_a)\wedge\mu_2(Z_b)\wedge\mu_1(Z_c)\wedge\mu_1(V_d);\; G_{14}=\mu_2(Z_a)\wedge\mu_2(Z_b)\wedge\mu_1(Z_c)\wedge\mu_2(V_d);\\
&G_{15}=\mu_2(Z_a)\wedge\mu_2(Z_b)\wedge\mu_2(Z_c)\wedge\mu_1(V_d);\; G_{16}=\mu_2(Z_a)\wedge\mu_2(Z_b)\wedge\mu_2(Z_c)\wedge\mu_2(V_d).
\end{aligned}$$

The third layer of neurons is used to normalize the aggregation results:

$$\overline{G}_r=\frac{G_r}{\sum_{r=1}^{16}G_r}. \quad (5)$$

The fourth layer is activated, as a result of which the individual conclusions of each fuzzy rule are determined by the formula (2). In addition, the neurons of this layer calculate the product of the results of normalization and activation:

$$g_r=\overline{G}_r Y_r. \quad (6)$$

The predicted value is determined by defuzzification performed by the fifth layer of neurons. In this case, the results of the functioning of the fourth layer of the system are added:

$$\tilde{R}_e=\sum_{r=1}^{16}g_r. \quad (7)$$

To obtain the values of the coefficients $x_1^{a1}, x_2^{a1}, x_1^{a2}, x_2^{a2}, x_1^{b1}, x_2^{b1}, x_1^{b2}$, $x_2^{b2}, x_1^{c1}, x_2^{c1}, x_1^{c2}, x_2^{c2}, x_1^{v1}, x_2^{v1}, x_1^{v2}$ and x_2^{v2} it is necessary to adjust the weights of the neurons of the first layer, and to obtain the values, $y_1^r, y_2^r, ..., y_5^r$ it is necessary to adjust the weights of the neurons of the fourth layer. It is proposed to adjust the fuzzy neural system based on the application of the error back propagation algorithm [13,14]. For training neurons, the data is formed, presented in the form of the following matrix:

$$\begin{bmatrix} Z_1 & Z_2 & Z_3 & V_4 & R_5\\ Z_2 & Z_3 & Z_4 & V_5 & R_6\\ . & . & . & . & .\\ Z_i & Z_{i+1} & Z_{i+2} & V_{i+3} & R_{i+4}\\ . & . & . & . & .\\ Z_{I-4} & Z_{I-3} & Z_{I-2} & V_{I-1} & R_I \end{bmatrix}, \quad (8)$$

where Z_i - is the number of packets received for transmission over the channel in cycle number i; V_i - is the value of the channel bandwidth allocated for the transmission of packets of a given class in cycle number i; R_i - is the number of packets of a given class discarded in cycle number i with passive control of the corresponding queue, $1\le i\le I$.

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To obtain matrix (8) during I = 500 observation cycles, the required parameters of one of the output ports of the router of a real telecommunications network were measured. The neuro-fuzzy system was adjusted using eight training cycles. The results of training neurons of the first layer are presented in table 1, and the fourth layer - in table 2.

Table 1

Results of training neurons of the first layer

Parameter	x_1^{a1}	x_2^{a1}	x_1^{a2}	x_2^{a2}	x_1^{b1}	x_2^{b1}	x_1^{b2}	x_2^{b2}
The values	0,011	11,02	0,031	12,04	0,021	12,05	0	12,04
Parameter	$x_1^{\bar{n}1}$	$x_2^{\bar{n}1}$	$x_1^{\bar{n}2}$	$x_2^{\bar{n}2}$	x_1^{v1}	x_2^{v1}	x_1^{v2}	x_2^{v2}
The values	0,032	12,07	0,021	11,99	2	17	2	17

Table 2

Results of training neurons of the fourth layer

r	**Coefficient values**				
	y_1^r	y_2^r	y_3^r	y_4^r	y_5^r
1	0	0	0,1843	0,5265	0,0262
2	0	0,1801	-0,0316	0	0
3	0	-0,-2457	0,6134	0,1773	0,0887
4	-0,053	0,2965	0,027	-0,002	-0,0006
5	0,0011	0,0014	0,0003	0,0003	0,0003
6	-0,025	0,1876	0,2702	0,1634	0,0409
7	0,0003	-0,0856	-0,1105	-0,0245	-0,0123
8	-0,1062	0,3229	0,3492	0,2753	0,0687
9	0	0	0	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	-0,0664	-0,0796	-0,1194	-0,0531	-0,0134
13	0,0037	0,0047	0,0016	0,0011	0,0008
14	-0,05	-0,075	0	-0,0333	0,0088
15	0,0011	0,0014	0,0003	0,0003	0,0002
16	-0,1327	-0,1592	-0,2389	-0,1062	-0,0267

In the Matlab software environment, a number of simulation experiments were performed to assess the forecasting accuracy of the fuzzy neural system of the number of dropped packets. In figure 6 shows the results of one of the experiments. In fig. 6 shows that in cycles i = 1 ... 7, 4 packets were transmitted over the channel, and in cycles i = 8 ... 12, the value of V_i decreased to 2 packets transmitted during each cycle.[13-16].

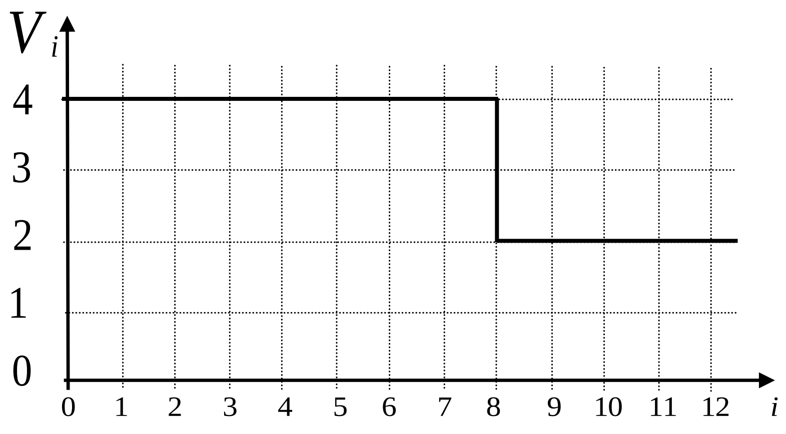

Figure 6. V_i values used in the simulation experiment

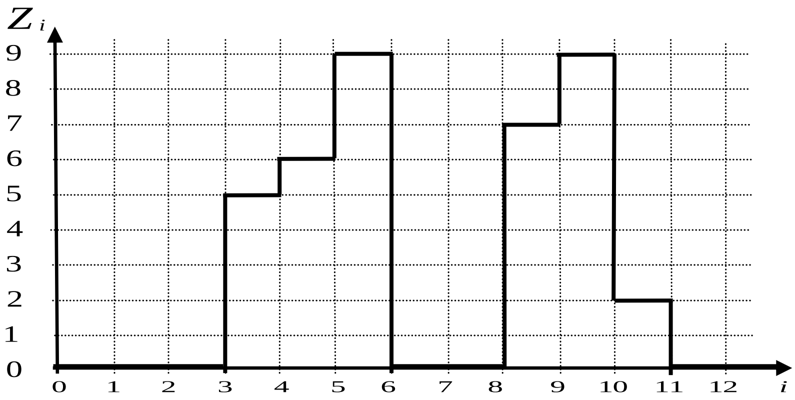

Figure 7. Z_i values used in the simulation experiment

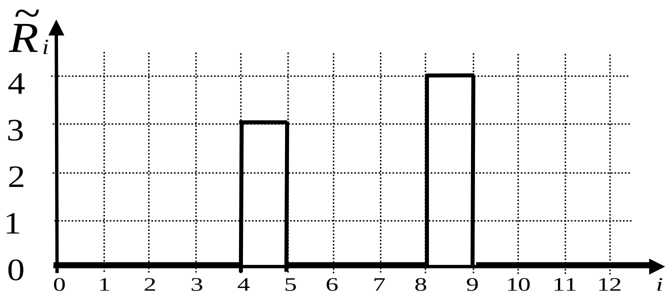

Figure 8. $\breve{R}_i$, values obtained in the simulation experiment

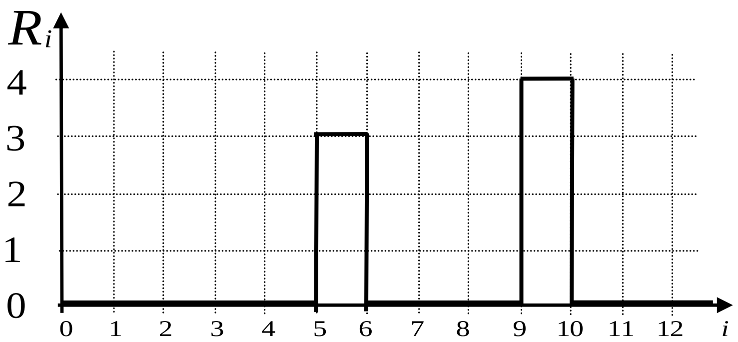

Figure 9. R_i, values observed in the simulation experiment

This decrease in the allocated bandwidth led to the fact that against the background of the increase in the number of received packets Z_i observed in cycles 8 and 9 (see Figure 7), the number of dropped packets in cycle 9 increased compared to cycle 4 ($R_9 > R_4$).

The analysis presented in Figure 8 and Figure 9 of the results shows that the predicted value of $\breve{R}_i$, which is calculated by the neuro-fuzzy system in each current cycle i, practically coincides with the real values of the number of dropped packets R_i recorded in the next cycle (i + 1). The prediction accuracy, established as a result of numerous simulation experiments, is 95–97%.

Initial data for carrying out simulation experiments

Parameter name	Value
Number of segments in the data stream	300
Segment bit length	15 kbit
Telecommunication channel bandwidth	2 Mbps

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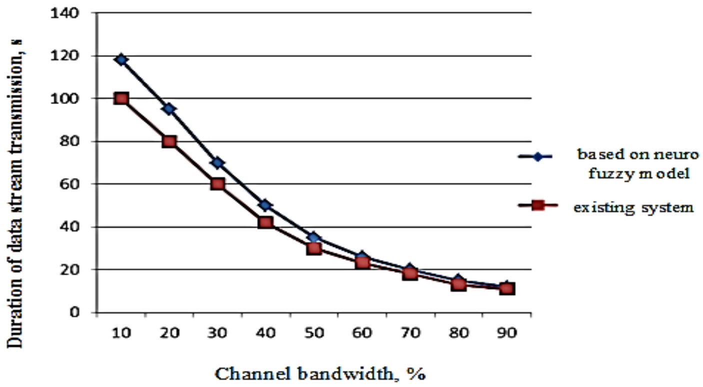

Figure 10. Dependence of the duration of the data stream transmission on the average available bandwidth of the channel

Conclusions. To compare the results obtained with the same initial data, a series of simulation experiments was carried out using a model in which the choice of an intersegment interval was implemented based on the use of a fuzzy inference system. The results of the experiments are presented in graphs showing the dependence of the duration of the data flow and the loss of segments on the average available bandwidth of the telecommunication channel. On these graphs, solid curves show the characteristics of the data stream transmission obtained using neuro-fuzzy selection of the inter-segment interval, and the dashed curves show the results of the management of the inter-segment interval based on the application of the system. The analysis of the presented dependencies shows that when transmitting a data stream over a channel, the available bandwidth of which does not exceed 50%, the use of a neuro-fuzzy system to select an inter-segment interval provides a decrease in segment losses by 5.2–11.3% and a decrease in the average time of streaming data by 7.1-12.3%.

Thus, a neuro-fuzzy model has been developed, designed to select the inter-segment interval in a telecommunications network. Unlike the existing ones, this model is based on the use of a fuzzy neural network apparatus. The results of simulation showed that the use of the developed model of the shortage of available channel capacity will ensure a decrease in segment losses and a decrease in the average transmission time of data streams.

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ADVANTAGE OF USE OF PROGRAMMING LANGUAGES IN TEACHING PHYSICS AND DESCRIPTION OF PROCESSES (ON THE EXAMPLE OF PYTHON PROGRAMMING LANGUAGE)

Khudayberdiyeva Arofat Isroilovna
head of the department of physics and electrotechnics, candidate of pedagogical sciences, PhD, Tashkent chemico-technical institute

Abstract:

Background. *The most important task for teachers of secondary special and higher education today is to further improve the quality of training, to organize the educational process, to stimulate students' independent thinking and to find the most effective teaching methods and tools to shape their needs for new knowledge. The use of interactive methods and e-learning literature in the educational process allows not only to increase interest in future specialization, but also educational activities in science. The article provides instructions on the use of one of the modern interactive methods of teaching physics, namely, methods of modeling processes, existing problems in this area and recommendations for their solution. All offers are illustrated with specific examples. At the present stage of society's development, students need a quality education. In this regard, the article considers the use of electronic textbooks in physics and existing software modules in the process of teaching students of technical specialties.*

Problem. *Despite the measures taken by the state to improve the quality of education, the majority of students graduating from secondary special and higher education institutions in recent years have little or no knowledge of modern computer programs. The point is that the student, the future specialist, now needs to know the algorithm, in general, the ways to solve it, the stage, when he is asked a more serious problem. The problem is that they understand the problem, know the ways, stages, and methods of solving it systematically. To do this, the student must develop these skills throughout the lessons. At the same time, it is important that teachers develop the ability to model the process during lectures and practice.*

Methods. *In order to explain the problem raised in the article as examples, the problem of the spring is selected, and the method of its theoretical and numerical-graphical solution is given. Each of the results obtained was explained using known rules and software.*

Conclusion. *In general, the use of computer technology in education allows to increase the level of mastery of the material and increase the attractiveness of the subject under study. It was found that the proposed methodology, compared with the traditional method, develops students' algorithmic, logical and independent thinking, allowing them to express their ideas independently through the final result obtained.*

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