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**THE USE OF NEURAL NETWORK TECHNOLOGIES IN  
RESEARCH COMPETENCE FORMATION OF IT-SPECIALISTS FOR THE  
RAILWAY INDUSTRY IN MULTILEVEL TRAINING SYSTEM  
ВИКОРИСТАННЯ НЕЙРОМЕРЕЖНИХ ТЕХНОЛОГІЙ У ФОРМУВАННІ  
ДОСЛІДНИЦЬКОЇ КОМПЕТЕНТНОСТІ ІТ-ФАХІВЦІВ ЗАЛІЗНИЧНОЇ ГАЛУЗІ ЗА  
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**Abstract.** The article considers the development of formation methods of research competence with the use of neural network technologies of IT specialists for the railway industry in multilevel training system. The proposed method «ResCompStageNNT» consists of the following stages: the determination of the current load of the MPLS domain tunnels (for the Bachelor's degree applicants); clustering the traffic flows under the condition of SOM-based QoS parameter and determining the MPLS domain tunnels on the basis of MLP (for the Master's degree applicants); distribution of the traffic flows by the tunnels of the MPLS domain on the created software package and the organization of a relevant research (for candidates of the Doctor of Philosophy's degree). The formed research competence of IT specialists of the railway industry provides an opportunity for the ability to research existing and design new computer networks of the information and telecommunication system of railway transport using the neural network technologies.

**Key words:** railway transport, degree, research competence, traffic, routing, MPLS, QoS parameter, neural network technology.

**Анотація.** У статті висвітлено питання розробки методики формування дослідницької компетентності з використанням нейромережних технологій у ступеневій підготовці ІТ-фахівців залізничної галузі. Запропонована методика «ResCompStageNNT» складається з таких етапів: визначення поточної завантаженості тунелів домену MPLS (для здобувачів ступеня «бакалавр»); кластеризації потоків трафіку за умови параметру QoS на основі SOM та визначення тунелів домену MPLS на основі MLP (для здобувачів ступеня «магістр»); розподіл потоків трафіку за тунелями домену MPLS на створеному програмному комплексі та організації відповідних досліджень (для здобувачів ступеня «доктор філософії»). Сформована дослідницька компетентність ІТ-фахівців залізничної галузі дає змогу дослідження діючих та проектування нових комп'ютерних мереж інформаційно-телекомунікаційної системи залізничного транспорту з використанням нейромережних технологій.

**Ключові слова:** залізничний транспорт, ступінь, дослідницька компетентність, трафік, маршрутизація, MPLS, параметр QoS, нейромережна технологія.

## Introduction

**Formulation of the problem.** At the present stage, the organization of routing in computer networks which form the basis of the information and telecommunication system of railway transport (ITS), is solved using the OSPF protocol. Nevertheless, such a routing protocol is not able to work in conditions of changing network configuration and traffic flow intensity considering several metrics while determining the optimal path. This requires the research of the other approaches to routing in the rail ITS computer networks.

**Analysis of recent research.** The solution to this problem is possible with the use of new transport technologies; in particular, the multiprotocol switching technology using labels (Multiprotocol Label Switching, MPLS) on the one hand, and the use of neural network technologies, on the other hand [3]. The characteristics of MPLS [1, 5-7] on the basis of analytical and simulation models were highlighted by the modern scientists such as Budyldina N.V., Goldstein A.B., Olifer V.G., Pasko S.P., Romanov O.I., Rukkas K.M., Sharadka A.M., Zaichenko O.Yu., Zaitsev D.A. and others. The conducted studies have shown that the use of MPLS technology can increase traffic by an average of 1.7 times. The solution of the routing problem in computer networks can be found on the basis of the following neural networks (NN): Hopfield's network, multilayer perceptron, RBF network, etc. However, it should be noted that at present there is a very limited number of scientific sources with relevant research on the organization of routing in the MPLS network with using neural network technologies, in particular the ITS of railway transport.

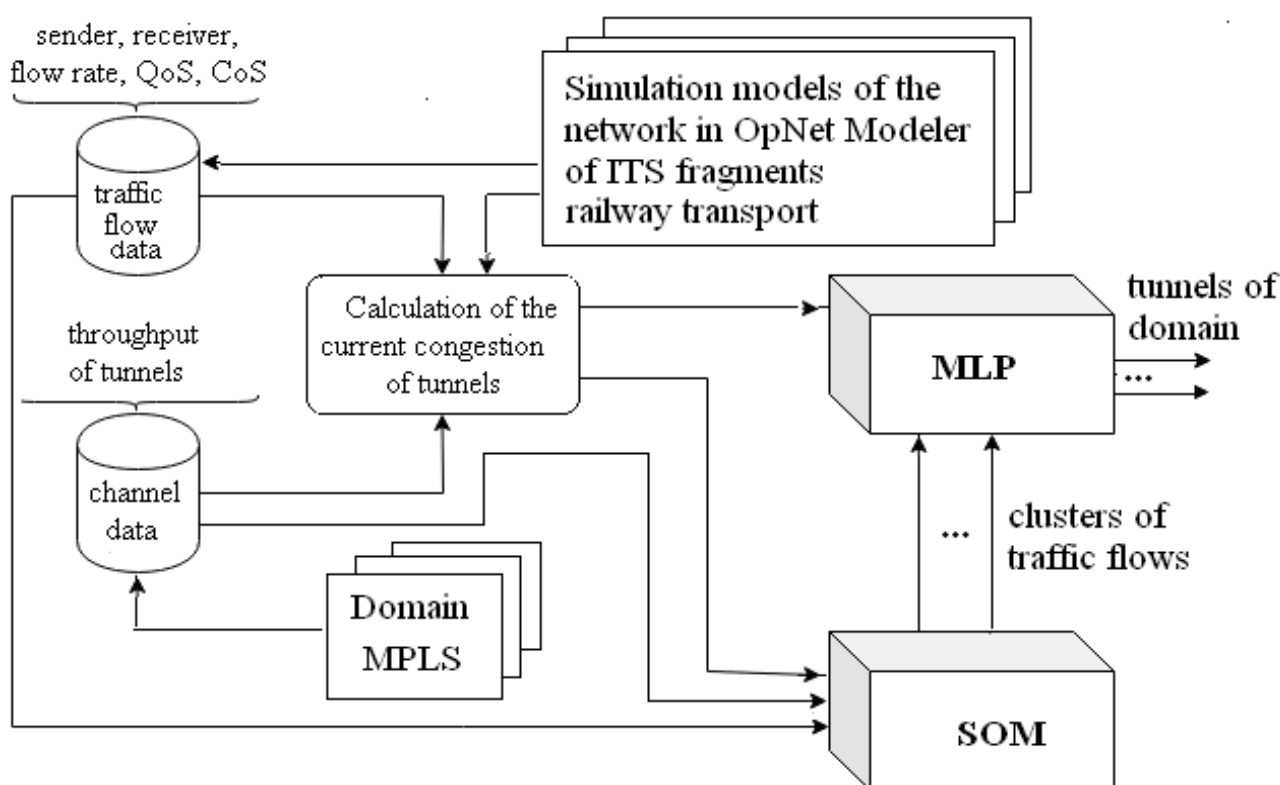
**The purpose of the article** is to develop a methodology for the formation of research competence with using neural network technologies ("ResCompStageNNT") for the multilevel training of IT specialists in the railway industry.

**1. Brief description of the "ResCompStageNNT" methodology.** The general structure of the proposed routing system for MPLS in the ITS of railway transport which is based on the use of the such NN as SOM (Self Organizing Maps) for clustering traffic flows and MLP (Multi Layer Perceptron) for identifying tunnels of the MPLS domain is presented in fig. 1. Classes of service (CoS) of traffic flows are assigned according to the selected parameter of quality of service (QoS), namely the maximum time of packet transfer (Maximum Packet Transfer Delay, maxPTD).

The formation of the research competence of IT specialists in the railway industry (specialties "Computer Engineering", "Cybersecurity", "Computer Science") is facilitated by the following cycle of disciplines: "Local Area Networks" (LAN) for first degree applicants; "Computer Network Design Theory" (CNDT) for the second degree applicants; "Network Technologies" (NT) for the third degree applicants.

**2. Research competence formation in the Bachelor's degree applicants.** The dependence of the solution quality of the traffic engineering problem on the sequence of assignments of the MPLS network flows is performed in the research [2]. In the framework of an individual educational research task (IERT) in the LAN discipline, the first degree applicants were offered to find a solution based on the use of NN, build it in MatLAB using the Neural Network Toolbox, and conduct necessary research to determine its optimal parameters: the number of hidden neurons;

activation function; learning algorithm; sample length.

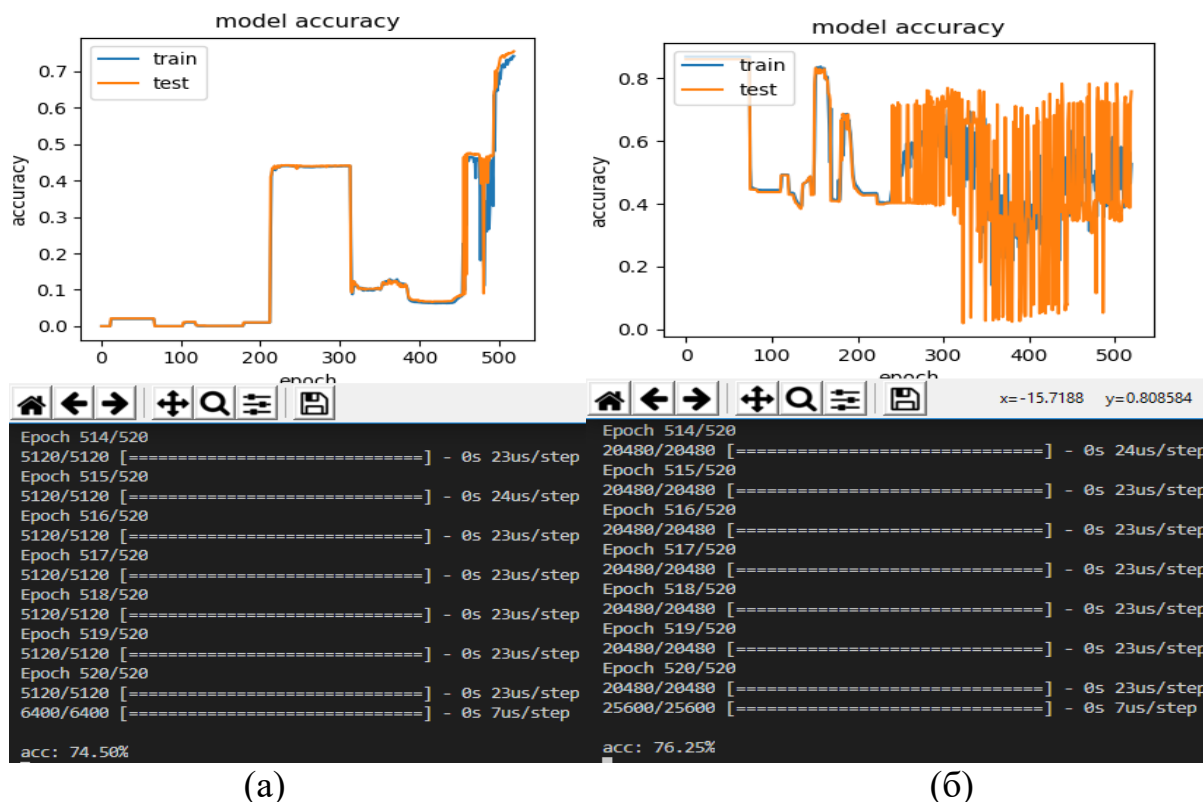


**Fig. 1. General structure of the routing system in MPLS**

*Author working*

**3. Research competence formation in the Master's degree applicants.** At the preparatory stage, the simulation models of the MPLS network of various fragments of ITS of railway transport created in the Opnet Modeler system by students of the second educational degree in practical classes on the CNDT discipline were used [4]. The results obtained on simulation models operating in different scenarios (IP, MPLS and MPLS TE) have proved the effectiveness of using MPLS TE. In addition, within the course project on the CNDT discipline being conducted in the MatLAB system, the Master's degree applicants were offered to create SOM for clustering the traffic flows based on maxPTD and MLP to define MPLS domain tunnels. Samples for SOM and MLP were formed on the basis of data obtained with the simulation model of the MPLS network in the Opnet Modeler system.

**4. Research competence formation in the Doctor of Philosophy's degree applicants.** Applicants of the third degree on the NT discipline were offered to create a software model of traffic flow distribution in the MPLS network which generates a sample for NN and its implementation. The programming language was chosen by an applicant according to his/her personal wishes and abilities. For example, the research of the parameters of NN was carried out on the software model "CoSThDist" created in Python by means of Keras framework. It was determined that the optimal solution is NN configuration 18-3-36-10 with the Softplus activation function in hidden layers [8] which under using the optimizer Adam provides accuracy of 74.5 % for 520 epochs on the samples from 6,400 examples (fig. 2).



**Fig. 2. Study of the sample length influence on the accuracy of the NN forecast:**  
**(a) - 6,400 examples; (b) - 25,600 examples**

### Conclusions

1. The research competence formation of IT specialists for the railway industry in degree education system with the use of neural network technologies is facilitated by the proposed method "ResCompStageNNT" consisting of the following stages: determining the tunnels current load of the MPLS domain (in the framework IERT of the LAN discipline for the first degree applicants); clustering of traffic flows considering the QoS parameter based on SOM and determining tunnels of the MPLS domain based on MLP (within conducting the course project on the CNDT discipline for the second degree applicants); traffic flows distribution in the tunnels of the MPLS domain on the basis of the created software package and organization of research (study of the NT discipline for the third degree applicants).

2. Nowadays, 4\*4 configuration of SOM is created that allows to distribute the traffic flows under the maximum packet transmission time from 50 to 100 ms; MLP configuration 18-3-36-10 with the Softplus activation function in hidden layers which under using the optimizer Adam provides an accuracy of 74.5 %. Further research should be performed taking into account other QoS parameters, in particular Packet Delay Variation (PDV) from 1.5 to 5 ms.

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