PRINCIPLES OF NEURO-FUZZY-BASED INTELLIGENT ROUTING IN DATA COMMUNICATION NETWORKS

D.M. Matkurbonov., K.A. Abdisoatov

Abstract. *The development of data communication networks and the increasing complexity of their topologies have increased the demand for efficient routing methods. This thesis considers the principles of intelligent routing based on Neuro-Fuzzy Systems in data communication networks. The proposed approach is based on integrating the learning capability of artificial neural networks with the decision-making mechanism of fuzzy logic. Interface buffer load, routing metrics generated by routing protocols, and route reliability are selected as the main parameters. The study results indicate that Neuro-Fuzzy systems represent a promising approach for processing uncertain information and forming intelligent routing mechanisms.*

Keywords: *data communication networks, intelligent routing, Neuro-Fuzzy system, neural network, routing metrics, route reliability.*

Introduction

The development of data communication networks is characterized by increasing complexity in their structure and topology, as well as the growth of transmitted traffic volume. This increases the importance of routing, since the efficient selection of routes directly affects network performance, reliability, and the efficient utilization of network resources. Traditional routing methods are not always capable of rapidly adapting to dynamic changes in network conditions, which necessitates the use of intelligent approaches in complex network environments. One of the main challenges in solving routing problems in packet-switched data communication networks is the need to consider multiple parameters simultaneously when forming routing metrics. The continuous variation of these parameters and the absence of clearly defined boundaries in certain cases lead to uncertainties in routing decision-making.

Principles of Neuro-Fuzzy-Based Routing

In practice, network conditions are often evaluated using concepts without strict numerical boundaries, such as “high load”, “low delay”, and “low packet loss”. Fuzzy logic is considered an effective tool for processing such uncertain information and supporting decision-making processes. At the same time, artificial neural networks provide capabilities for learning from data, identifying hidden relationships, and adapting to changing environments [1]. Neuro-Fuzzy systems,

which combine the capabilities of fuzzy logic and artificial neural networks, are considered one of the promising approaches for comprehensive network state evaluation and improving routing efficiency. This approach enables decision-making based on uncertain information, adaptation to changes in network parameters, and the formation of intelligent routing mechanisms.

The objective of this study is to analyze the principles of intelligent routing based on Neuro-Fuzzy systems in data communication networks and investigate their application capabilities.

Literature review

Improving routing efficiency in data communication networks has become one of the important directions of modern scientific research. Studies conducted in this area cover issues related to routing process optimization, decision-making based on uncertain information, and the application of artificial intelligence techniques.

Research presented in [2] proposed a genetic algorithm for optimizing message routing in computer network environments. The author considered a multi-objective mathematical programming model to achieve minimum cost and minimum delay within the network. Although the study demonstrated the effectiveness of the optimization approach, it also emphasized the necessity of using hybrid approaches to further improve decision-making capabilities.

The authors in [3] proposed a fuzzy logic-based approach for routing decision-making. In this study, routing parameters were incorporated as components of a fuzzy system, and a rule-based decision-making mechanism was developed. The proposed approach enabled processing of uncertain information and reduced the dependency on complex expert rules.

Research presented in [4] introduced a Neuro-Fuzzy system model for improving routing processes. The model combines the learning capability of artificial neural networks with the decision-making capabilities of fuzzy logic. The results indicated the potential for improving routing performance and selecting optimal routes under dynamic network conditions. However, the limited number of parameters used in the model may restrict its applicability to different network environments.

The analysis of existing studies indicates that although current approaches effectively address certain aspects of routing processes, there remains a need to further improve intelligent decision-making methods for multi-parameter and dynamic network environments. Therefore, developing principles of intelligent routing based on Neuro-Fuzzy systems remains an important research direction.

Intelligent Routing Model Based on a Neuro-Fuzzy System

Neuro-Fuzzy systems combine the decision-making capabilities of fuzzy logic with the adaptive learning characteristics of artificial neural networks. In data communication networks, this approach enables routing decisions to be made by considering the current network state. Under dynamic changes in network parameters, a Neuro-Fuzzy system can adaptively adjust the significance level of routing criteria according to changing conditions. The general architecture of Neuro-Fuzzy-based intelligent routing in data communication networks is shown in Figure 1.

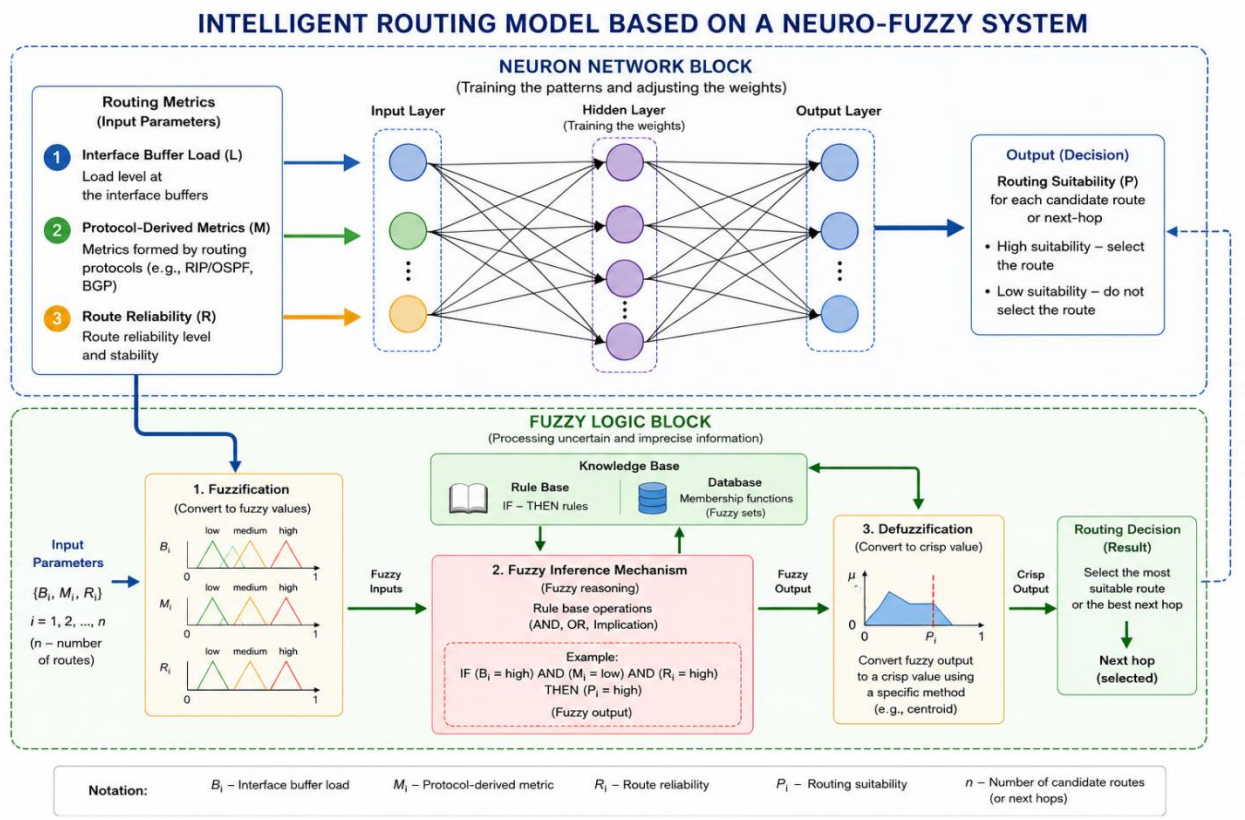

Figure 1. Architecture of an Intelligent Routing Model Based on a Neuro-Fuzzy System

In the proposed Neuro-Fuzzy routing model, the input parameters include the interface buffer load level Bi, the routing metric generated by the routing protocol Mi, and the route reliability indicator Ri. The interface buffer load level represents the current load condition of a network node, the routing metric reflects the characteristics of the packet transmission path, while the route reliability indicator provides an assessment of transmission stability and availability.

Initially, these parameters are transformed into fuzzy sets during the fuzzification stage, and their values are represented by linguistic variables such as

"low", "medium", and "high". In the next stage, routing decisions are generated using a fuzzy inference mechanism and a knowledge base. Artificial neural networks perform the task of adapting the weighting coefficients of system parameters and adjusting them according to network conditions [6-7]. Finally, during the defuzzification process, fuzzy outputs are converted into precise values, routing priorities are determined, and the optimal next-hop node is selected.

Conclusion. The literature analysis indicates that intelligent approaches are among the promising directions for improving routing efficiency in data communication networks. Existing methods enable the consideration of multiple parameters, processing of uncertain information, and adaptation to dynamic network conditions. The findings show that fuzzy logic is effective for handling uncertain information, while artificial neural networks provide learning and adaptive capabilities. Therefore, a Neuro-Fuzzy approach considering interface buffer load, routing metrics, and route reliability can serve as a promising solution for forming intelligent routing mechanisms in data communication networks.

REFERENCES

1. R.X. Djuraev, Sh.Yu. Djabbarov, D.M. Matqurbonov, Sh.X. Magdiyev. Kommutatsiya va Marshrutizatsiya. Toshkent –«Nihol Print» OK-2024 y., 240 b.
2. Akpan E. E. "Genetic Algorithm for optimizing message routing in Computer Network environment". Thesis, FUTA, 2011.
3. Arnold W., Hellendoorn H., Seiseng R., Thomas C., Weitze A. "Fuzzy routing". Fuzzy Sets and Systems, 85, 1997, pp. 131–153.
4. Odekunle K. A., Alese B. K., Abiola O. B. "Neuro-Fuzzy System for Routing in a Computer Network". International Journal of Computer Applications, Vol. 68, No. 9, April 2013.
5. Sugacini Mohankumar., Yaashuwanth Calpakkam., Prathibanandhi Kanagaraj. Neuro Fuzzy Deep Reinforcement Learning for Energy Optimized Routing in Large-Scale Wireless Sensor Networks
6. Rustam Djurayev., Dilshod Matkurbonov., Urinov Khojiakbar. Analysis of a Model for Improving the Efficiency of Routing Control in Data Transmission Networks Based on Fuzzy Logic. In Communications (Vol. 11, Issue Number 1, June 2023) ISSN Print: 2328-5966; ISSN Online: 2328-5923
7. RK Djuraev, SY Djabbarov, DM Matkurbonov, OA Khasanov. Modeling the performance of a data network router using queueing theory with simulation and analytical validation. Optical and Computational Technologies for Measurements and Industrial Applications (OptiComp 2025). SPIE. 190-195