ANALYSIS OF APPROACHES TO INCREASE THE EFFICIENCY OF DATA COMMUNICATION NETWORKS

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Abstract. *This paper provides information on traditional, perspective and intelligent approaches to increase the efficiency of data communication networks. The possibilities of applying the theory of fuzzy sets to the functional model of a router to form a multi-parameter route metric in routing processes are also considered.*

Keywords: *data communication networks, packet switching, router, routing processes, route metric, theory of fuzzy sets.*

Modern data communication networks (DCNs) are complex and expensive information technology complexes, the quality of operation of which can significantly affect the efficiency of the functioning of economic, social and other systems that depend on them [1].

It is known that due to the generation of uneven traffic by each network user in real time through modern network applications, the traffic burst ratio increases from 1:50 to 1:100, as a result, the routing process becomes a logical bottleneck of the data communication network (Fig.1).

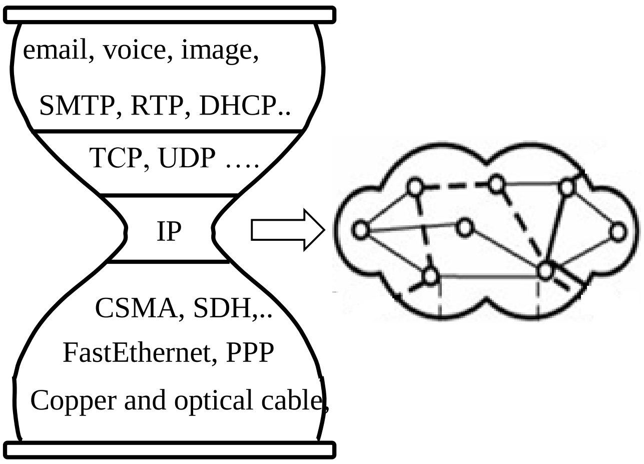

Fig.1. Bottleneck of the TCP/IP model

The main reason that the routing process becomes a logical bottleneck in the data network is that the router performs all the packet processing functions at the network layer of the TCP/IP model. These functions analyze fields in the packet header entering the router, such as checksum verification, traffic filtering and packet service determination, packet lifetime, and more.

These features, in turn, result in increased routing table lookup time, buffer queuing delays, and increased CPU load, resulting in packet loss due to router buffer overflow and affecting router performance [2].

International and domestic practice shows that existing routing methods and algorithms used in IP-based DCNs currently do not fully meet modern requirements for:

– failure to meet quantitative requirements for the reliability of modern data communication networks;

– the performance of switching nodes and the effectiveness of the routing methods and algorithms used;

– insufficient level of flexibility and automation of existing methods and tools for managing network resources.

The above disadvantages are due to the following main factors:

– rapid growth in traffic volumes, changes in its structure and nature (primarily the exponential growth of mobile and video traffic in networks due to the widespread use of smartphones and tablets);

– rapid growth in the number of users connected to the network using mobile and wireless technologies and various devices;

– complexity of scaling networks, insufficient flexibility of the system for managing network resources, services, etc.

Currently, there are three approaches to increasing the efficiency of DCN:

– **the traditional approach,** by increasing the number of hardware performance of network switching nodes, as well as the throughput of communication channels (but this is associated with high costs for maintaining a management system for network resources and the network as a whole);

– **the perspective approach,** associated with a complete update of the DCN telecommunications infrastructure, that is, with the transformation of the network architecture itself based on the technologies of software-defined SDN networks and virtualization of NFV network functions. However, this approach is associated with significant costs and low adoption rates: it is currently used in data center networks.

– **An intelligent approach** by increasing the efficiency of using existing network resources through the development and research of routing methods and algorithms. In this regard, numerous developments are underway to improve routing methods and algorithms, give routers a more "intelligent appearance," and implement priority traffic processing schemes.

One of the main problems when solving routing problems in DCN based on packet switching is the need to take into account many factors when choosing a route metric, namely: link capacity, packet loss, delays, reliability, number of transit nodes, network load, buffer size and other parameters. Using several factors allows you to model the network more accurately. One of the promising ways to form a multi-parameter route metric based on the functional characteristics of the router and the state of the channel is to use the mathematical apparatus of fuzzy set theory (FS). Generating route metrics based on fuzzy set theory has a number of advantages:

- redirecting packets through the network automatically;
- network load stabilization;

– acceleration of data delivery over the network;
– reduce the human factor to a minimum.

Fuzzy logic mechanism consists of fuzzification, composition and defuzzification stages in the formation of fuzzy decision [3].

The first step of fuzzification is to determine the input and output parameters and their corresponding fuzzy linguistic variables. The set of allowed values of linguistic variables is called term-set. In FS, it is formalized through fuzzy sets using the membership function. The main tool of the fuzzy logic apparatus is the relevance function.

The membership function $M_A(x)$ is a certain mathematical function that defines the degree or confidence of belonging to a given fuzzy set A given the elements of a given set x. The more the argument x corresponds to the fuzzy set A, the larger the value of $M_A(x)$ that is, the closer the value of the argument is to one. The main types of fitness functions: linear (triangular, trapezoidal), Z-shaped and S-shaped, P-shaped. Input and output parameters of system variables use the following relevance functions [4]:

The Z-shaped membership function is described as follows (1) :

$$f_z(x;a;b) = \begin{cases} 1, \ x \le a\,; \\ \frac{b-x}{b-a}, \ \ a < x < b; \\ 0, \ x \ge b. \end{cases} \tag{1}$$

The S-shaped membership function is described as follows (2) :

$$f_s(x;a;b) = \begin{cases} 0, \ x \le a\,; \\ \frac{x-a}{b-a}, \ \ a < x < b; \\ 1, \ x \ge b. \end{cases} \tag{2}$$

The triangular membership function is described as follows (3) :

$$f_\Delta(x;a;b) = \begin{cases} 0, \quad x \le a\,; \\ \frac{x-a}{b-a}, \ \ a < x < b; \\ \frac{c-x}{c-b}, \ \ b < x < c; \\ 1, \ x \ge c. \end{cases} \tag{3}$$

where a, b, c are numerical parameters satisfying the condition a <b <c.

The most commonly used logical operations are the OR operation to determine the maximum value and the AND operation to determine the minimum value. The minimum operation (min) is used as T-norm and the maximum operation (max) as S-norm [5]:

$$M_A(x) *^T M_B(y) = min[M_A(x), M_B(y)] \tag{4}$$

$$M_A(x) *^S M_B(y) = max[M_A(x), M_B(y)] \tag{5}$$

At the second stage of fuzzification, each linguistic variable is given a set of terms and sets of fuzzy variables corresponding to them.

These sets are characterized by characteristic functions that take values [0...1] that define the priority for the corresponding factor. In some cases, such functions can be determined objectively based on the conditions of the task, in other cases, subjectively based on common sense.

In the composition stage, matching conditions (rules) are required between input and output fuzzy variables. The formation of such rules is carried out by an expert and, as a rule, is subjective. The structure of the rules is determined based on the "if-then-else" format, and the semantics is determined based on the expert's knowledge and intuition. A rule base is a set of fuzzy rules. In the form of Rk, k=1…N:

$$R_k\text{: IF } (x_1 \text{ is } A_1^k \text{ and } x_2 \text{ is } A_2^k \text{ and } x_n \text{ is } A_n^k)\text{, then } (y_1 \text{ is } B_1^k) \quad (6)$$

where: x_i – input variables, A_i^k - the corresponding fuzzy set y_i – output variables, k=1…N fuzzy inference rules, N- number of fuzzy inference rules, (i=1…n).

An increase in the number of rules or fuzzy sets of a fuzzy model expands the possibility of describing a real system. However, with the increase in complexity, the amount of information representing the modeled system increases significantly. In addition, the amount of information about the modeled system may not be enough to build a more complex model, in which case the complexity of the model becomes its disadvantage.

If the number of inputs of the model x_i is denoted by ω, and each of them is given by the same number z of the fuzzy set, then the number of rules r is determined by the following formula:

$$r = z^{\omega} \quad (7)$$

The rule base should ensure that the fuzzy model achieves the required accuracy. At the same time, it is necessary to reduce the number of rules stored in the base as much as possible to reduce the calculation costs and ensure the model's transparency. Also, the list of rules can be supplemented and changed during the development and correction of the decision-making algorithm.

At the defuzzification stage, the fuzzy number is transformed into a unique number using M_B^i membership functions for each fuzzy symbol x_i. One of the defuzzification methods is the center of gravity method [4-6]:

$$\overline{x_i} = \frac{\sum_{j=1}^{N} M_B(a_j) \cdot a_j}{\sum_{j=1}^{N} M_B(a_j)} \quad (8)$$

Based on the rules developed in the defuzzification process, the value of the corresponding "exact" variable is calculated.

To develop a functional model of a router based on fuzzy sets, it is proposed to apply a fuzzy logic system to the level of the routing protocol (Fig. 2).

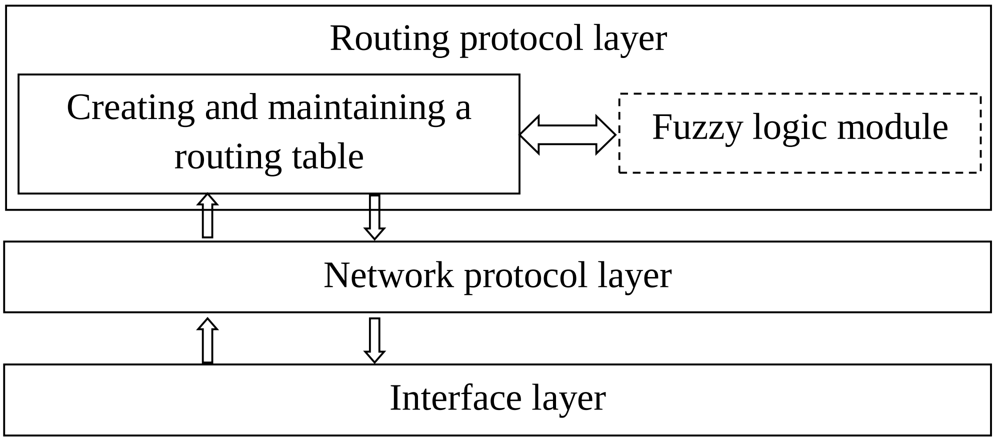

Fig.2. A functional model of a router based on fuzzy sets

This proposed router functional model is described as follows: after the packet header is processed by the network protocol layer, the route metric is calculated according to the routing table located in the routing protocol layer. When calculating the route metric, the multi-parameter route metric based on the functional characteristics of the router and the channel state is formed using the fuzzy logic control module and transmitted to the lower layer.

Conclusion. The application of the mathematical apparatus of the theory of fuzzy sets to routing processes leads to the possibility of working without changing the configuration of the existing standard protocols, the full use of the internal resources of the router, that is, to further expanding the capabilities of its technical means, such as internal memory and processor, which in turn, it causes an increase in DCN productivity. Thus, the algorithms created on the basis of FS introduce a method of systematic analysis into the routing process, which allows the development of new routing algorithms and the modernization of existing ones.

REFERENCES

1. Stallings W. Data and computer communications. Pearson Education, Inc. Pearson Prentice Hall, 2007.

2. Ш. Одом, Х. Ноттингем. Маршрутизаторы CISCO /– М.: Кудиц-Образ, 2003. – 528 с.

3. Леоненков А. В. Нечеткое моделирование в среде MATLAB и fuzzyTECH / – СПб.: БХВ–Петербург, 2005. – 736 с.

4. Rustam Djurayev, Shukhrat Djabbarov, Dilshod Matkurbonov, Amir Lazarev, Orif Khasanov. Increasing the efficiency of network resources in IP

networks based on fuzzy sets. International Conference on Information Science and Communications Technologies (ICISCT), 2021. Tashkent, Uzbekistan.

5. Матқурбонов Д.М. Модель системы управления маршрутизацией с использованием нечетких множеств. “Мухаммад ал-Хоразмий авлодлари” илмий-амалий ва ахборот-таҳлилий журнали. Тошкент. 2023, №1 (23), - Б. 76-81

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