DOI: 10.5604/01.3001.0010.8545

IMITATION MODELING OF THE ROUTING PROCESS BASED ON FUZZY LOGIC

Ivan Lesovoy, Genadij Pylypenko
Odessa National A.S. Popov Academy of Telecommunications, Infocommunication Faculty, Telecommunication systems Department

Abstract. *The paper discusses the details of modeling of the routing process according to the loading of output buffer storage. Shows the obtained dependence of the fraction of lost packets from the input intensity. It is shown that taking into account buffer occupancy increases the efficiency of their use and can significantly affect the quality of the functioning of the telecommunications network in the face of considerable.*

Keywords: fuzzy logic, routing, load, packet loss

MODEL SYMULACJI PROCESU ROUTINGU OPARTEGO NA LOGICE ROZMYTEJ

Streszczenie. *W niniejszym artykule zostały omówione cechy symulacji procesu routingu uwzględniające nośność buforów wyjściowych napędu. Otrzymano zależność frakcji zagubionych pakietów od intensywności strumienia wejściowego. Wykazano, że uwzględnienie obciążenia bufora zwiększa efektywność ich użytkowania i może znacząco wpłynąć na wydajność sieci telekomunikacyjnej w warunkach znacznego obciążenia.*

Słowa kluczowe: logika rozmyta, routing, obciążenie, utrata pakietów

Introduction

In the past telecommunication network applications have used a modest percentage of bandwidth and no one of those applictions had QoS requirements. Currently, the prevalent use of topology-driven IP routing protocols with shortest-path computations is causing serious imbalance of packet traffic distribution when least-cost paths converge on the same set of links, leading to unacceptable dela ys or packet loss even when feasible paths over less utilized links are available.

At this time, applications have been routed through network as best effort services. As we know, best effort services are not suitable for multimedia applications.

Congestion occurs when the telecommunications network uses network resources unevenly, there is blocking, or when the number of packets received by the network to transport between users exceeds a certain threshold.

In the process of controlling the queue for hypothetical traffic, the waiting time in the queue and the probability of an overflow of the input buffer are calculated [2]. If the probability of buffer overflow and buffer overflow corresponds to the desired QoS, then a new traffic packet is received.

The search for the best route is carried out in a network with indistinctly defined parameters since switching units and transmission channels parameters used to determine the metrics in routing protocols may change. Telecommunications network load is not a uniform and it changes through time.

In the loading buffer management system based on a rigid logic, excessive requirements for limited resources telecommunication network by one or more users can reduce the quality of service for other users. Additionally, there are some problems that can occur during this transmission, especially in aspect of delays, bandwidth and packet losses. Therefore it is desired to design some intelligent controlling mechanisms for solving different problems in a network. In order to design the above mention intelligent mechanisms in network platform we have used theory of fuzzy sets. Solve the problem of designing an adequate metric allows fuzzy logic based on the theory of fuzzy sets.

In this paper, we propose a fuzzy-logic based algorithm for routing under traffic engineering constraints. The proposed Fuzzy Routing Algorithm (FRA) modifies the well known protocol EIGRP [4], by using fuzzy-logic membership functions in the – buffer load control process.

1. Routing based on fuzzy logic

With the development of telecommunication networks, there are more and more additional factors that must be considered in routing algorithm, which points to the need to improve routing protocols through analysis and evaluation performance. To improve the routing algorithm adequacy, the metric should take into account some more factors. An important factor in choosing a route is the degree of utilization of the output buffer, which determines, or discard of the packet or redirection of it by a longer route whose buffers are less loaded. However, as a rule, the degree of buffer loading in determining the metric is not taken into account. The switching nodes and transmission channels used to calculate the metric may vary due to the fact that:

- the buffer space of routers is restricted;
- the reliability of lines and equipment transport network is limited;
- signals distributed to the network are exposed to random nature noise;
- to handle packet in router need some time;
- the length of the messages are independent.

Thus, finding the optimal route is in a network with fuzzy parameters or sets of parameters. In a network with fuzzy parameters to describe the inaccurate category, ideas and knowledge to operate them and make appropriate conclusions we used fuzzy logic the theory it is based on fuzzy sets.

Fuzzy logic is tolerant in imprecise data, nonlinear functions and can be used with other techniques for different problems solving. The main principle of fuzzy logic is using fuzzy groups which are without crisp boundaries.

In particular the fuzzy logic controllers is useful in two special cases:

- when the control processes are too complex to analyze by conventional quantitative techniques;
- when the available sources of information are interpreted qualitatively or uncertainly.

When choosing the best route the routing algorithm based on fuzzy logic allows set factors considered. In this case the most acceptable for systems for control the traffic is linguistic fuzzy decision-making model. Given that traffic control is carried out in real time, and hassle formalization information on the procedures and conditions for their use, with the description of knowledge, it is advisable to use productive model (a set of fuzzy production rules).

The concept of "fuzzy logic" was introduced by Zadeh (1965). He proposed the theory of "fuzzy sets", which can be used to construct fuzzy analogs of all mathematical concepts and to create necessary formal techniques for simulation of human reasoning and human way of solving problems. The theory of "fuzzy sets" deals with "human knowledge" which is called "expert information".

Fuzzy logic introduces a simple, rule-based IF X AND Y THEN Z approach to solving the management problem, rather than trying to model the system mathematically. Fuzzy logic describes the behavior of the operator during control. Fuzzy logic is based on the empiricist (experience) of the operator, and not on understanding the insides of the system. Fuzzy logic uses some numerical parameters to estimate the load and the rate of change in the load, but exact values of these quantities are usually not required.

For example, instead of using the exact values of buffer loading, we are dealing with rules like "IF (the download is small) AND (rate of change in the load is small) THEN (increase the number of packets for transmission through this interface)" or "IF (large buffer loading) AND (the load increases rapidly) THEN (redistribute packages on alternative routes)".

These statements are inaccurate and at the same time describe what really happens. Usually fuzzy logic allows the system to work from the first time without any adjustment.

A Fuzzy Logic Controller is a rule based system in which fuzzy rule represents a control mechanism. In this case, a fuzzy controller uses fuzzy logic to simulate human thinking.

A fuzzy control is characterized by immediate application of qualitatively formulated expert knowledge for generation of control actions on the controlled object (process) is represented by rules of the form: if (initial situation), then (response). Such rules correspond to the elementary form of human interactions.

In order to get a traffic control system on the base fuzzy logic, need to describe the states and actions of the system using fuzzy rules in natural language.

The concepts of "a linguistic variable", "linguistic quantity" and "membership function" $\mu(x)$ play the central role in the theory of fuzzy sets. The function $\mu(x)$ determines the degree of membership of an element (linguistic variable) x to a fuzzy set (to a term) X in the form of a numerical value within the range [0, 1] (this numerical value is called "the degree of truth" of a linguistic variable). A fuzzy set is described completely by its membership function. For example, representing the linguistic quantity (fuzzy subsets) "negative", "positive", "large" and "small" by the linguistic variable "an error" through their membership function, the ranges of variation in the qualitatively described physical quantity. The membership function of linguistic quantities, as a rule, overlap each other; therefore, these functions can inform of different nonzero values of "degree of truth".

In Ukraine, the concept of "fuzzy-logic" introduced by Zadeh means the illegible logic; therefore, illegible controllers are named also fuzzy-controllers, and control systems with fuzzy-controllers the fuzzy-systems.

Fuzzy logic controller consists of: fuzzifier, rule base, fuzzy inference and defuzzifier. A fuzzifier operator has the function of transforming crisp value input variable to fuzzy set. Rule-Base (Linguistic Rules): Contains IF-THEN rules that are determined through fuzzy logic. Fuzzy Inference is a process of converting input values into output values using fuzzy logic. Converting is essential for decision making. Fuzzy Inference process includes: membership functions and logic operation. Defuzzifier identifies crisp value of control action. Converting process of fuzzy terms in crisp values is called defuzzification.

The use of fuzzy controllers (regulators, operating on the basis of fuzzy logic) to control the various (in particular, nonlinear and non-stationary) objects shows their high efficiency and in a number of cases their significant advantages over digital linear regulators [3].

The functional diagram of the router based on fuzzy logic is shown in Fig. 1

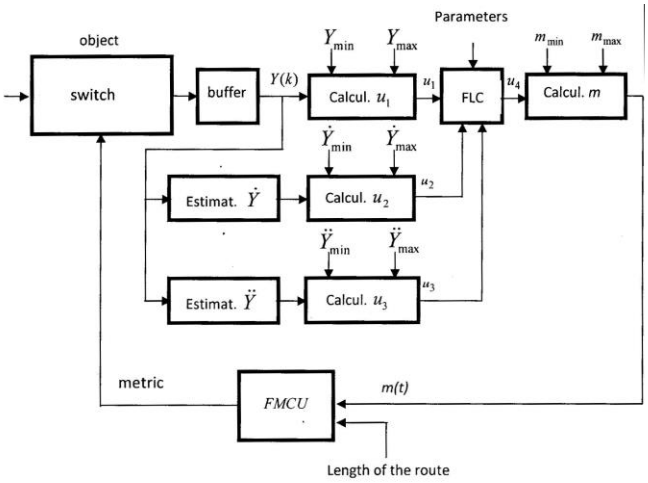


Fig. 1. Structure of the router based on fuzzy logic unit (FLC – fuzzy logic controller, FMCU – fuzzy metric calculate)

The most acceptable systems control the flow of burden is linguistic fuzzy decision-making model. Given that load control is carried out in real time, and hassle formalization information on the procedures and conditions for their use, with the description of knowledge, it is advisable to use productive model (a set of fuzzy production rules). Each fuzzy production rules allows of matching situation that has developed an action.

The conversion of current values of the input variables of a fuzzy-controllers into linguistic variables of the degree of truth is called fuzzyfication. In a fuzzy-controller, a logic decision is formed on the basis of IF-THEN rules (a rulebase). Deriving a control action at the output of a fuzzy-controller in the form of a resulting membership function (in the form of the fuzzy set) and the generation of the output variable of a fuzzy-controller (of a control action on a controlled object) are called de fuzzyfication.

The conversion of current values of the input variables of a fuzzy-controllers into linguistic variables of the degree of truth is called fuzzyfication. In a fuzzy-controller, a logic decision is formed on the basis of IF-THEN rules (a rulebase). Deriving a control action at the output of a fuzzy-controller in the form of a resulting membership function (in the form of the fuzzy set) and the generation of the output variable of a fuzzy-controller (of a control action on a controlled object) are called de fuzzyfication.

As input variables are proposed to use value-load buffer Y, utilization rate of change (first derivative) $\dot{Y}$, and acceleration (second derivative) $\ddot{Y}$ workload. Output variable controls action on the object of control m .

The main parameters of digital fuzzy controllers in which their synthesis and calculation were performed, are, firstly, the number and shape of membership functions $\mu^T(u)$ of linguistic variables and, secondly, ranges of input and output linguistic variables load buffer, the first derivative of load buffer, the second derivative load buffer control action on the switch, i.e.

$$[Y_{\min}, Y_{\max}],\ [\dot{Y}_{\min}, \dot{Y}_{\max}],\ [\ddot{Y}_{\min}, \ddot{Y}_{\max}],\ [m_{\min}, m_{\max}]. \quad (1)$$

Number of functions of MF (the number of terms that describe the input and output variables) limits, if possible, the least number [3]. For each linguistic variable you can use your membership functions. Thus, there is a fairly large number of options for assigning membership functions when optimizing the parameters of the fuzzy controller.

Membership functions take triangular. Correction of triangular MF to expert data, is performed by exponentiation, where the exponent determines the change in the form of MF.

In universal set of given two fuzzy sets, membership function which is monotone for each linguistic value (terms positive -1, negative -2)

$$\mu^1(u) = 1 - u; \quad \mu^2(u) = u; \quad u \in [0, 1].$$

Fig. 2 shows the triangular membership functions of the device for controlling the load output buffer of the router functioning on the basis of fuzzy logic.

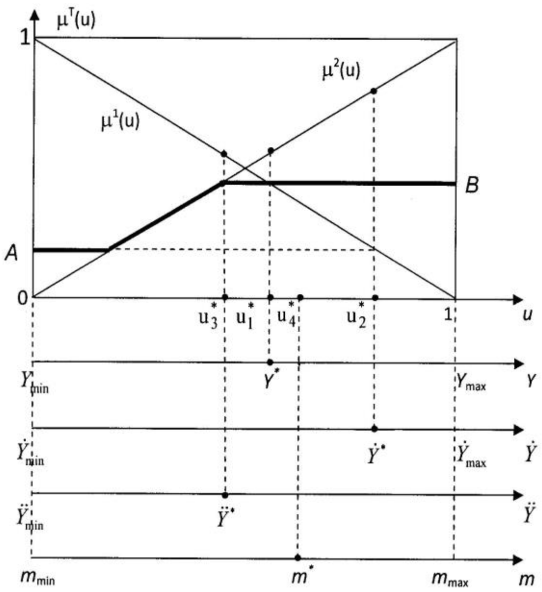


Fig. 2. The triangular membership functions of the device for controlling the load of the output buffer

In order to gain better results at the output of the FLC, one important role plays selection of defuzzification method. There are some defuzzification methods: COG (Centre of Gravity), COGS (Centre of Gravity for Singletons), COA(Centre of Area), LM (Left Most Maximum) and RM (Right Most Maximum).

Three most important methods are: COG, MOM and LOM. It is important to find which method gives better results in aspect of routing.

Centre of Gravity method determines the centre of resultant shape that is gained from membership functions with AND and OR logic operators. Formula with which we can calculate the defuzzified crisp output U is given:

$$U = \frac{\int_{Min}^{Max} u\mu(u)du}{\int_{Min}^{Max} \mu(u)du},$$

where: U is defuzzification result; u – output variable; μ – membership function; *Min* – minimum limit for defuzzification, *Max* – maximum limit for defuzzification.

With formula we can calculate the surface of resultant shape and also we can find central point. Projecting this point in the abscissa axis determines the crisp value after defizzification.

The resulting membership function was obtained by the Mamdani method.

The abscesses center of gravity $s_c = S(u_c, \mu_c)$ calculation in resultant shape (MF) $\mu(u)$ within the range of the variable u from $u = U_1$ to $u = U_2$, are determined using numerical integration the trapezoids method

$$u_c = \frac{\frac{U_1\mu_1}{2} + \sum_{i=1}^{M-1} u_i\mu_i + \frac{U_2\mu_M}{2}}{\frac{\mu_0}{2} + \sum_{i=1}^{M-1}\mu_i + \frac{\mu_M}{2}},$$

where: $(U_2 - U_1)/M = u_0$ sampling step; M – the number of readings on the interval $U_2 - U_1$, i = 1, 2, 3, ..., M–1.

To test and analyze the effectiveness of the algorithm, experimental studies were performed.

2. Modeling process routing based on fuzzy logic

Routing metrics have a significant role, not just in complexity of route calculation but also in QoS, especially when we have to deliver triple play services. The use of multiple metrics is able to model the network in a more precise way, but the problem for finding appropriate path can become very complex.

Thus, it is important to take into consideration some metrics that play a key role in offering those services. Those metrics play a direct role in for delivering triple play services over packet network. In order to consider multiple metrics simultaneously, we will use the main component of soft computing, so called fuzzy logic.

Controller based on fuzzy logic is called fuzzy logic controller (FLC). FLC is intelligent technique that can manipulate with two or more input parameters simultaneously without any problem.

The process of passing packets flow through the node distribution information is random and similar processes in queuing systems. Routers serviced packet flows received from subscribers and transmission channels of adjacent units. Streams of incoming packets and processing time are random, so the entrance formed network processor queue for service. To maintain the router packages that may not serve the currently prescribed buffer storage. That inlet distribution unit sold procedure information service with expectations.

After processing processor packages are sent to one of the transmission channels adjacent node. The time depends on the transmission capacity of the selected path and the length of the package and is a random variable. So at the entrance of each transmission path also implemented the bulk of service expectations. So is a two-phase model of router queuing system.

An important factor is the degree of choice route congestion source junction that determines the appropriateness or drop packet forwarding it more extended route, which buffers are not loaded. However busy junction buffer storage in determining metrics is usually not taken into account.

In the process of routing expediently to consider not only the distance but also dynamic load corresponding output buffer drive interface and a number of other factors. It should be considered that when choosing the best route factors influence the set allows routing algorithm based on fuzzy logic. Research methods of load control based on fuzzy logic executed for the most common protocol EIGRP.

For study the efficiency of EIGRP routing protocol based on fuzzy logic, is developed simulation model, under such assumptions: packets entering the router are characterized by priority, length and the remainder of life-time.

The remainder of the packet lifetime in the model is given by the random variable with exponential distribution. Packet loss simulated router sending the package to the clipboard is full, so the request is not served and the number of counter requests is not granted, it is incremented.

Sometimes service packages in the router and eventually spread signal transmission path are ignored and the router queue is not limited. The length of the packet is a random variable with exponential distribution and average value $\overline{l_n}$. The main input stream is a Poisson with intensity λ_0. The capacity of all output channels of 10 Mbit/s. Functional circuit simulation model is shown in Fig. 3.

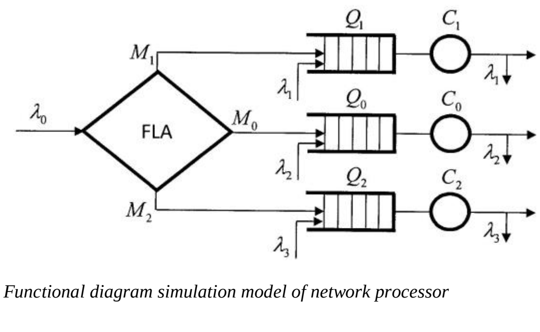


Fig. 3. Functional diagram simulation model of network processor

Model network processor consists of a fuzzy implement routing algorithm (FLA) and three output buffers to drive the main (M_0) and two alternative routes (M_1, M_2).

The direction of the packets to the appropriate buffer storage is carried out in accordance with a modified protocol EIGRP based on fuzzy logic. $Q_0, Q_{1,} Q_2$ – the queue in output buffer router joints.

Loading telecommunications network to network processor is simulated by introducing into each output buffer more incoming flow Poisson intensity λ_i ($i = 1,\ldots, 3$). After passing through the flow further paths are removed.

The proposed model of the network processors uses "soft" computing [3]. With fuzzy production rules, a linguistic approximation of the process of selecting transmission channels is performed based on their bandwidth and dynamic load output buffers drives.

In the simulation efficiency of routing it was estimated the ratio of lost packets to the total number of packets transferred [4]. Lost packets dependence on the intensity of the input stream is given in the table.

Table 1. Dependence Lost packets on the intensity of the input stream of packets.

Intensity of the input stream, Mbit/s		0	15	30	45	60	90	120	150
Lost packets dependence	EIGRP	0	0,1	0,33	0,48	0,62	0,69	0,75	0,76
	EIGRP with FLA	0	0	0	0,29	0,47	0,59	0,73	0,76

The traffic control system for "hard" logic takes a decision to route only alternative route in case of exceeding a certain value workload output buffer. Network processor based on fuzzy logic controlling the dynamic load output buffers of the first manifestations of the increase in their workload, which have no effect on the efficiency of the telecommunications network in advance direct flow of packets alternative routes.

Routing algorithm based on fuzzy logic would reduce the share of lost packets by 30 percent if the intensity of the input stream equal to the total throughput capacity of output channels and 10 percent if the intensity of the input stream exceeds the total bandwidth output channels doubled. This shows at improving the quality of routing since packets are not lost, and sent to alternative routes are not loaded, providing efficient use of the resource router [1].

3. Conclusions

The analysis methods of design metrics in different routing protocols not found profound reflection in the metric of all aspects of the network. Despite the complexity of routing algorithms, the number of factors is taken into account in the metric remains low (1–4 factors).

To improve the adequacy of the routing algorithm, the metric should consider more factors. Solve the problem of designing a new metric based on fuzzy sets theory allows and it is based on fuzzy logic.

The results reported in this paper show that FRA achieves traffic distribution at higher loads without increasing the path-request blocking probability. The analysis of the results shows that when using a fuzzy set of routing algorithms, the average queue length and waiting time in the packet in the queue is somewhat increasing, indicating a more complete use of the router's resources.

The use of fuzzy logic is easily possible to create a scalable system routing logic which makes it easy to build and change the structure of metrics on a systematic basis by expanding the (changing) rules base for route selection. Studies have shown that with the use of fuzzy sets in problems routing opens up new possibilities of management based on simple heuristic rules and adaptation to extreme and non-stationary traffic.

Taking into account the dynamics of load buffers increases the efficiency of their use, contributing to the optimization of the network (reducing time distribution packages, reducing the share of lost packets, simplifying the requirements for buffer memory and storage interfaces.). Given the significant workload resources telecommunications network may significantly affect the quality of operation.

Optimizing the parameters of the regulator during the design and implementation of the router does not take much time. Automation of the process of debugging the router based on fuzzy logic will significantly reduce the development and commissioning time of routers based on fuzzy logic.

References

[1] Kleynrok L., Hrushko Y.Y., Neyman V.Y.: Teoriya massovogo obsluzhivaniya. Mashinostroyeniye. Moscov 1979.

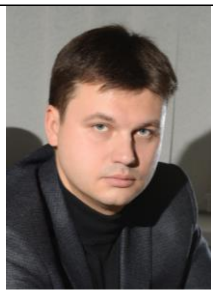
[2] Lozhkovskyy A.H., Verbanov O.V.: Pydvyshchennya tochnosty rozrakhunku kharakterystyk yakosty obsluhovuvannya pry samopodyvnomu trafyku merezhy. Naukovi pratsi ONAZ im. O.S. Popova 1/2015, 36–41.

[3] Pospelov D.A.: Sytuatsionnoe upravlen′ye: Teoriya i praktyka. Nauka, Moscov 1986.

[4] Vrublevskyy A.R., Lisovyy I.P., Pylypenko H.V.: Modelyuvannya protsesu marshrutizatsii na osnove nechetkoy logiko za protokolom EIGRP. Modelyuvannya ta informatychni tekhnolohiyi 77/2016, 145–147.

Prof. Ivan Lesovoy
e-mail: ur5fo55@gmail.com

Lesovoy Ivan Pavlovich Doctor of Technical Sciences (2005), Professor (2008). Professor of the Department of Telecommunication Systems, Institute of Information and Communication Technologies and Computer Engineering of Odessa National Academy of Telecommunications the name of A.S. Popov. Author of more than 100 scientific works, including 10 monographs, 5 textbooks. Research interests: fuzzy logic in telecommunications, digital processing and signal generation in telecommunication systems.



M.Sc. Genagij Pylypenko
e-mail: gvpilipenko@gmail.com

Pylypenko Genadij Viktorovych postgraduate student of the department of Telecommunication Systems, Institute of Information and Communication Technologies and Computer Engineering of Odessa National Academy of Telecommunications, the name of A.S. Popov. Author of 8 scientific works. Research interests is packet network traffic management on the fuzzy logic base.

otrzymano/received: 10.10.2017 *przyjęto do druku/accepted: 15.02.2018*