Application of Fuzzy Logic for Routing in Communication Networks

Anton Vrublevsky, Ivan Lesovoy

Abstract –**To satisfy QoS requirements we should take into consideration routing metrics that affect directly to the QoS.**

We will consider three parameters: bandwidth, losses and delays. For transmitting multimedia services it is desired to design some controlling mechanisms for solving different problems in a network in case of packet delays, losses etc. Because of complex nature of controlling mechanisms it is desired to design fuzzy logic controller.

As input parameters will be three routing metrics mentioned above, whereas as output parameter will be network efficiency. The aim is to obtain better values of network efficiency using different rules from Rule Editor and using appropriate defuzzification method.

Keywords – **fuzzy logic, linguistic variables, mambership function, fuzzy logic controller, fuzzy rules, routing metrics.**

I. INTRODUCTION

Enhanced Interior Gateway Routing Protocol (EIGRP) is an enhanced version of Cisco's Interior Gateway Routing Protocol used in TCP/IP and OSI internets. Key capabilities that distinguish EIGRP from other routing protocols include fast convergence, support for variable-length subnet mask, support for partial updates, and support for multiple network layer protocols.

A routing protocol EIGRP can uses for its metrics:

- Bandwidth
- Delya
- Raliability
- Load

The metric for EIGRP is calculated by formula:

metric = [K1 * bandwidth + (K2 * bandwidth) / (256 - load) + K3 * delay] * [K5 / (reliability + K4)]

Just a minor correction, substituting for the K values in the metric formula does not straight away reduce to metric = (bandwidth + delay)*256. The factor [K5 / (reliability + K4)] will zero the whole metric! My understanding (I could be wrong) is that if it is zero (0), it is simply left out and not used. Note the bandwidth and delay values we used are those configured on the interface through which the router reaches its next hop to the destination network. There are some problems that can occur during transmission of multimedia services, especially in aspect of delays, bandwidth and packet losses. Therefore it is desired to design controlling mechanisms used fuzzy logic for solving different problems in a network.

Anton Vrublevsky, Ivan Lesovoy, – Odessa National Academy of Communication, Kuznechnaya Str. 1, Odessa, 65029, UKRAINE, E-mail: ur5fo@mail.ru

II. A PROPOSED CONTROLLING MECHANISM

The problem of optimizing routing decisions has been one of the most intensively studied areas in the field of communication networks. Optimization of routing decisions means optimizing routing metrics, as metrics are bfoundation for routing decisions. Therefore, a lot of efforts has been done by the routing community in this direction.

Optimization of routing decisions means Route metrics that are used to make this decision are bandwidth, losses and delays currently in a path. It is proposed here that the metrics bandwidth, losses and delays in a path will be combined into a single decision thereby optimizing a routing protocol over a number of metrics and making it more robust.

For delivering multimedia services over packet switch network, we need to do a deep analysis of these three metrics that affect directly in the network efficiency. Using membership functions for three abovementioned Metrics allows us to define threshold values for each metric. Also we will define here a set of rules, one rule per each metric, defining thus an acceptable range or a minimum/maximum acceptable value for bandwidth, delays and losses.

Bandwidth is one the main parameters in packet switch network. In this case we will define 2 membership functions that show the scale of bandwidth: low and high. Bandwidth is expressed with triangular membership functions.

Delay is the most important parameter for the most of applications, especially for triple play applications. For transmitting one service between two points, delays are one of the most important parameters for QoS guarantee that indicate directly in better link efficiency. For delay we also have defined 2 triangular membership functions to show the scale of delays that can be: acceptable and intolerable.

Losses for delivering triple play services over packet switch network, the most critical parameter that we should take into consideration is loss. For losses we have defined 2 membership functions: acceptable and intolerable. When the percentage of packet losses is above 0.1 % then we will have serious problems with quality of figure in IPTV.

Fuzzy logic is tolerant in imprecise data, nonlinear functions and can be mixed with other techniques for different problems solving.

The decision to continue with a network will be determined via a fuzzy logic system being applied to a fuzzifier that translates them into fuzzy sets. A fuzzifier operator has the effect of transforming crisp value to fuzzy sets. Fuzzifier is presented with $x = fuzzifier(x0)$, where $x0$ is input crisp value; x is a fuzzy set and fuzzifier represents a fuzzification operator.

The fuzzy sets are used to appraise each constraint as being Low or High, assigning each a value between {0, 1}. These

evaluations are passed to a fuzzy inference engine that applies a set of fuzzy rules that determines if a route is apt for continue or not. If a route is deemed suitable then the route request is rebroadcast and the node extracts and caches the route record. When a route request arrives at the necessary destination a route reply is generated and sent to the initiator of the route request by reversing the path stored in the route record.

Example fuzzy rules for both *To continue* and *Not To not to continue with the route discovery process* conclusions are given below:

IF (L=High) AND (B= High) AND (D=Low) THEN continue to rebroadcast

IF (L=Low) AND (B=Low) AND (D=High) THEN stop rebroadcast

Where:

L = Losses

B = Bandwidth

D = Delays

The decision to or not continue with a route request rebroadcast is made by using the min-max rule, with the minimum value of the *To continue* rule set being taken as the outcome and likewise for the *Not To continue* set. The maximum value of these two outcomes is then selected as the conclusion for the decision.

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.

In particular the FLC is useful in two special cases:

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

Fuzzy logic controller consists of: fuzzifier, rule base, fuzzy inference and defuzzifierIn order to gain better results at the output of the

Fuzzy logic controller (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 link efficiency for offering triple services over pacet network.

In our case, we will use COG (Centre of Gravity), determines the centre of zone 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:

$$u = \frac{\frac{U_1 m_0}{2} + \sum_{i=1}^{M-1} u_i m_i + \frac{U_2 m_M}{2}}{\frac{m_0}{2} + \sum_{i=1}^{M-1} m_i + \frac{m_M}{2}}$$

where u is defuzzification result, U – *output variable*, μ - membership function, U_1 - minimum limit for defuzzification, U_2 - maximum limit for defuzzification, $(U_2 - U_1) / M = u_0$ – sampling step, M – number of sample in the interval $U_2 - U_1$; $i = 1, 2, 3, ..., M - 1$.

III. Conclusion

In this paper, we propose a fuzzy logic based decision as a route selection method. This cumulative path fuzzy logic system also generates route replies only for selected routes and not for all available routes.

Furthermore, Results show that fuzzy logic based rebroadcasting decision making enhances protocol performance as the route request overhead is lessened and the end-to-end delay associated with packets is reduced. Also, the packet delivery ratio is higher for our proposal as it is compared with EIGRP routing algorithm.

The improved protocol performance can be attributed to the fuzzy system as is selects stable routes.

We have taken into consideration three metrics of packets network in order to find better network efficiency. For taking into consideration 3 or more parameters it is hard job, but using fuzzy logic it is possible.

In this paper we will design fuzzy logic controller (FLC) using Matlab software. As input parameters that act in this FLC we took bandwidth, delays and losses.

The main part of FLC is defuzzifier that plays a key role for obtaining crisp values in the output. As e defuzzification method we used COG (Centre of Gravity) method.

Analysis of these metrics are made with MATLAB software and these analysis show that if the losses are bigger that 0.1% we will have problems in QoS.

So we can see that this parameter is very critical for QoS. But, also the two other parameters are very critical for QoS.

Reference

[1] Врублевський А.Р., Лісовий І.П. Керування навантаженням мережі на основі нечіткої логіки. 18 - Міжнародна конференція з автоматичного управління. АВТОМАТИКА/ AUTOMATICS – 2011, Львів, 28 – 30 вересня, 2011, с 238-239.

[2] Гостев В.И., Лесовой И.П., Чуприн А.Е. Оптимизация параметров цифровых нечетких регуляторов // Труды Междунар. конф. “АВТОМАТИКА-2001”. – Том 1. – Одесса: ОГПУ, 2001. – С. 21-22.

[3] Лісовий І.П. Методика параметричного синтезу цифрового регулятора на основі нечіткої логіки. Моделювання та інформаційні технології: Зб. наук. пр. ІПМЕ НАН України. – К.: 2004.– Вип. 26. – С. 23-28.