Selection of Defuzzification method for routing metrics in MPLS network to obtain better crisp values for link optimization

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Abstract: - The complexity of networks that offers multimedia services requires the consideration of multiple routing metrics for routing decisions. The most important metrics that should be considered for multimedia services are: delay, bandwidth, jitter, losses etc. This paper treats three network metrics as input parameters of fuzzy logic controller: delay, losses and bandwidth. As we know, the output of fuzzy logic controller depends from selection of defuzzification method. The aim is to obtain better values of link optimization in MPLS network using appropriate defuzzification method. Also, in this paper we will make some analysis with MATLAB to show which defuzzification method is the best one for better link utilization.

Key-Words: - metrics, fuzzy logic, defuzzification, fuzzy logic controller, multimedia services.

1 Introduction

In Internet, data packets that belong to traffic flow can follow different paths to the destination. This leads to a situation where network capacity is not guaranteed and delays are not limited. Said in other words, best-effort services [1] are not suitable for multimedia applications. Thus, it is necessary to present an architecture that supports new services in Internet and guarantees QoS for multimedia applications [2], [3], [4]. The network that offers multimedia services with high quality of service is MPLS network._ In order to analyze the link optimization in MPLS network, we should take into consideration some network metrics that affect directly in QoS. First we will explain a short introduction to MPLS network architecture that is deployed in Telecom of Kosova[5]. Further we will explain routing metrics that play a key role for offering QoS in MPLS network. FLC (Fuzzy Logic Controller) architecture is presented as intelligent controller as well as comparison between defuzzification methods for obtaining crisp values for link optimization in MPLS network in TK [6] (Telecom of Kosova). Finally, special attention is paid to the analysis of selection the best defuzzification method with MATLAB software.

2 MPLS network

MPLS is a data transmission technology which includes some features of circuit switched networks through packet switched network. MPLS actually works at both Layer 2 and Layer 3 in OSI model and it is often referred to as a Layer 2.5 technology. It is designed to provide transport possibilities of data for all users. MPLS techniques can be used as a more efficient tool for traffic engineering than standard routing in IP networks. Also, MPLS can be used for path control of traffic flow, in order to utilize network resources in an optimal way. Network paths can be defined for sensitive traffic, high security traffic etc, guaranteeing different CoS (Class of Service) and QoS. Main MPLS feature is virtual circuit configuration through IP network. These virtual circuits are called LSP.

MPLS supports traffic engineering for QoS provision and traffic prioritization, for example: provision of wider bandwidth and lower delays for gold customers who are able to pay more for better quality services. Another example a lot of paths can be defined through edge points by ensuring lower levels of interferences and backup services in case of any network failure. This is like using routing metrics in IP network to enforce traffic flowing in one or another direction, but in this case MPLS is much more powerful. An important aspect in MPLS is the priority concept of LSP **[7].** LSPs can be configured with higher or lower priority. LSPs with higher priority have advantages in finding new paths compared with those of lower priority. MPLS technology has been implemented in Telecom of Kosova, thus enabling converged IP network services, focusing on opportunities for service differentiation and service-oriented technology.

Figure 1 shows elements used for creation of MPLS network in Telecom of Kosova.

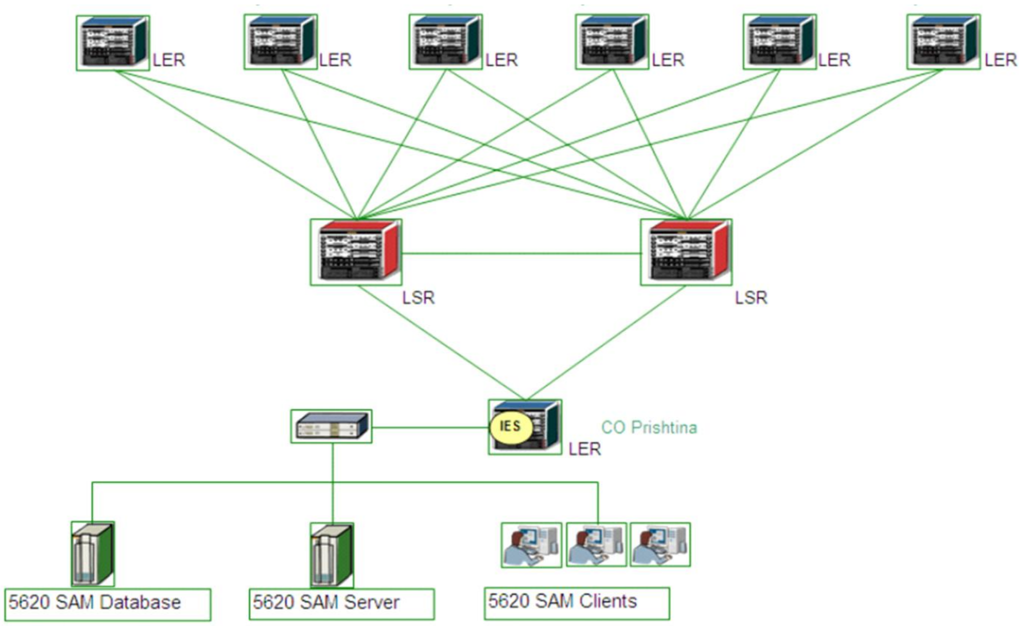


Figure 1. MPLS network architecture in Telecomm of Kosovo

The elements of this network are LERs (label edge router) which are located at the edge network (in all Kosova regions) and LSRs that are located in the core network. MPLS networks are designed to support different classes of multimedia services that fulfill QoS requirements. In this way, these networks have the possibility of video, voice and data transmissions in real time. However, MPLS networks have some disadvantages that have to do with delays during LSP creation or with QoS based routing: packet losses during LSP creation process and traffic congestion due to limitations in bandwidth. Some problems can occur during multimedia service transmission, therefore it is a good idea to design some control mechanisms for solving such problems [8]. As a result of the complex nature of control mechanisms, more and more is being done in designing intelligent controlled techniques. One of the intelligent controlled techniques that will be part of this paper is Fuzzy Logic Controller, a technique that is based on fuzzy logic. In this paper we will use three metrics as input parameters of FLC.

3 Routing Metrics in MPLS network

Routing metrics have a significant role, not just in complexity of route calculation but also in QoS. 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 [9] [10]. There are 3 types of metrics: additive, multiplicative and concave. They are defined as below: If m(n1, n2) are metrics for link (n1, n2). For one path $P=(n_1, n_2, \ldots, n_i, n_j)$, metric m is $(n_1, n_2, \ldots, n_i, n_j)$:

- Let $d(i, j)$ be a metric for link (i, j).

For any path $p=(i, j, k, \ldots, l, m)$, we say metric d is additive if:

$$d(p) = d(i, j)+d(j, k)+\ldots+d(l, m)$$

1. - We say that metric d is multiplicative if:

$$d(p) = d(i, j) \times d(j, k) \times \ldots \times d(l, m)$$

- We say that metric d is concave if:

$$d(p) = \min\,[d(i, j), d(j, k) \ldots d(l, m)]$$

In MPLS network there are a lot of metrics that we can take into consideration, but in this paper, for sake of simplicity, we will consider three main metrics: delay, losses and bandwidth. Those metrics play a direct role in quality of service in MPLS network. In order to consider multiple metrics simultaneously, we will use fuzzy logic controller. FLC is intelligent technique that can manipulate with two ore more input parameters simultaneously without any problem.

4 Fuzzy Logic Controller

A Fuzzy Logic Controller [13] 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: [11]

- 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 defuzzifier:

<u>Fuzzifier</u>: A fuzzifier operator has the effect of transforming crisp value to fuzzy sets. Fuzzifier is presented with x=*fuzzifier*(x_0), where x_0 is input crisp value; x is a fuzzy set and fuzzifier represents a fuzzification operator.

<u>Rule-Base (Linguistic Rules):</u> Contains IF-THEN rules that are determined through fuzzy logic.

Example: if x is A_i and Y is B_i the Z is C_i, where x and y are inputs and z is controlled output; Ai, Bi and Ci are linguistic terms, like: low, medium, high etc.

<u>Fuzzy Inference:</u> 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 operations

<u>Defuzzifier:</u> can be expressed by: y_{ou} = *defuzzifier*(y), where y identifies fuzzy controller action, y_{ou} identifies crisp value of control action and defuzzifier presents defuzzifier operator. Converting process of fuzzy terms in crisp values is called defuzzification. Fuzzy Logic Controller is shown in figure 2.

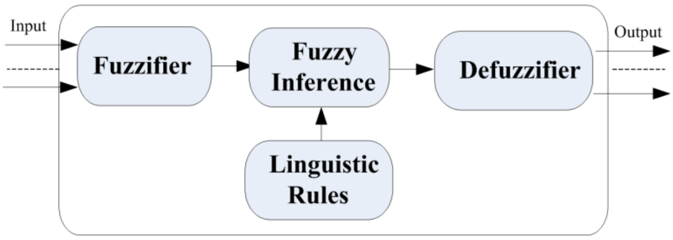


Figure 2. Fuzzy Logic Controller

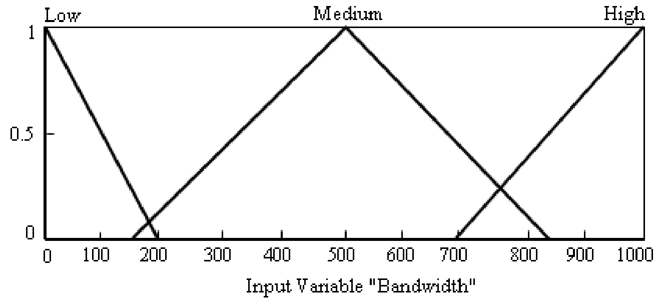
5 MPLS network metrics and membership functions

We will use MPLS network metrics as input parameters at the FLC input. These input parameters can be with crisp or fuzzy values. Since the main disadvantages of MPLS network consist in: loss, delay and bandwidth, then these three network metrics elements will be taken as input parameters. Then, we should define fuzzy membership function for input parameters. In this case we will use triangular membership functions. The table below presents input parameters in FLC and corresponding fuzzy sets to these parameters.

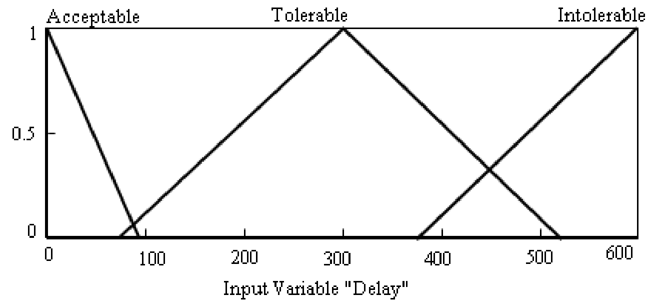
Table 1. Network Metrics and Fuzzy sets

Inputs	Fuzzy Sets
Bandwidth	{Low, Medium, High}-Mbps
Delays	{acceptable, tolerable, intolerable}-ms
Losses	{acceptable, tolerable, intolerable}-%

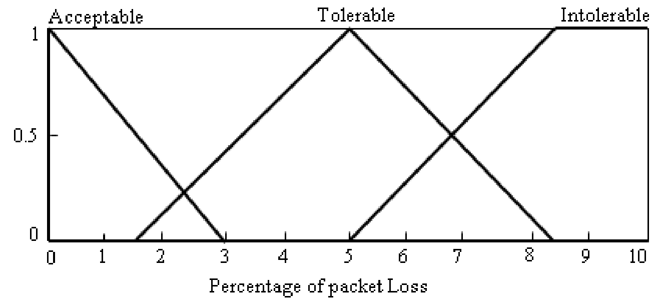
Membership functions for bandwidth, delays, losses and output of fuzzy system are shown in figure:



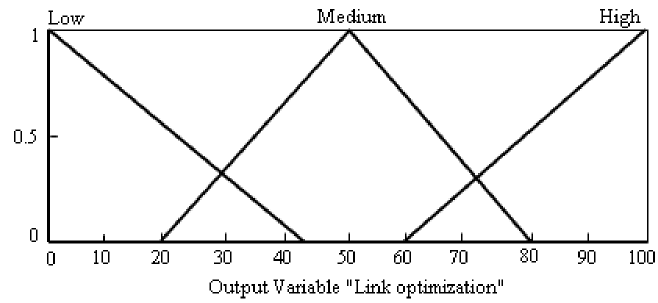
(a) Bandwidth (*Mbps*)



(b) Delays in ms



(c) Percentage of packet loss



d) Output of fuzzy system

Figure 3. a) membership function of bandwidth, b) delays, c) percentage of packet loss and d) output of fuzzy system.

Once the membership function and input parameters have been defined, fuzzy rules for relevant parameters can be written:

Fuzzy Rules derived from Rule Editor (Matlab) are:

Rule 1: *If (bandwidth is low) and (delay is acceptable) and (loss is acceptable) then (link optimization is Low)*
Rule 2: *If (bandwidth is Medium) and (delay is acceptable) and (loss is acceptable) then (link optimization is Medium)*
Rule 3: *If (bandwidth is High) and (delay is Acceptable) and (loss is Acceptable) then (link optimization is High)*
Rule 4: *If (bandwidth is Low) and (delay is Tolerable) and (loss is Acceptable) then (link optimization is Low)*
Rule 5*: If (bandwidth is Medium) and (delay is Tolerable) and (loss is Tolerable) then (link optimization is Medium)*
Rule 6*: If (bandwidth is High) and (delay is Tolerable) and (loss is Intolerable) then (link optimization is Medium)*
Rule 7*: If (bandwidth is Low) and (delay is Intolerable) and (loss is Acceptable) then (link optimization is Low)*
Rule 8*: If (bandwidth is Medium) and (delay is Intolerable) and (loss is Tolerable) then (link optimization is Low)*
Rule 9*: If (bandwidth is High) and (delay is Intolerable) and (loss is Intolerable) then (link optimization is Low)*

6 Selection of defuzzification method for finding crisp value for link optimization

For finding the appropriate path for transmission of multimedia services one important role plays selection of defuzzification method. There are 5 defuzzification methods: Centre of Gravity (COG), bisectorial, LOM (largest of maximum), MOM (middle of maximum) and SOM (smallest of maximum). Three most important methods are: COG, MOM and LOM. It is important to find which method gives better results in aspect of link optimization in MPLS network.

6.1 Centre of Gravity method

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

$$U = \frac{\int_{Min}^{Max} u \ \mu(u) du}{\int_{Min}^{Max} \mu(u) du} \qquad (1)$$

Where U is deffuzification result, *u = output variable*, $\mu = membership \ function$, *Min=minimum limit for deffuzification*, *Max=maximum limit for deffuzification*

With formula (1) we can calculate the surface of zone that is shown in figure below and also we can find one central point in this zone. Projecting this point in the abscissa axis determines the crisp value after defuzzification.

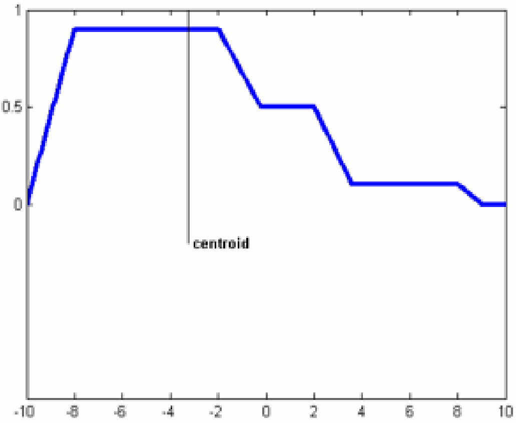


Figure 4. COG method

6.2 LOM (largest of maximum), MOM (middle of maximum) method

LOM method determines the largest of maximum value in the zone that is obtained from membership functions with AND and OR logic operators whereas MOM method determines Middle of maximum value in that zone.

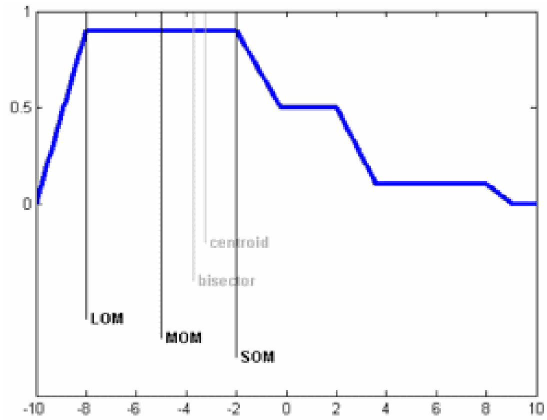


Figure 5. LOM, and MOM methods

In some cases MOM and LOM methods are better than COG method, but in general, for the most of cases, no matter what zone we will have, COG method shows better results. In this paper we will analyze which method is better with MATLAB software in 3 D.

7 MATLAB analysis for finding a better defuzzification method

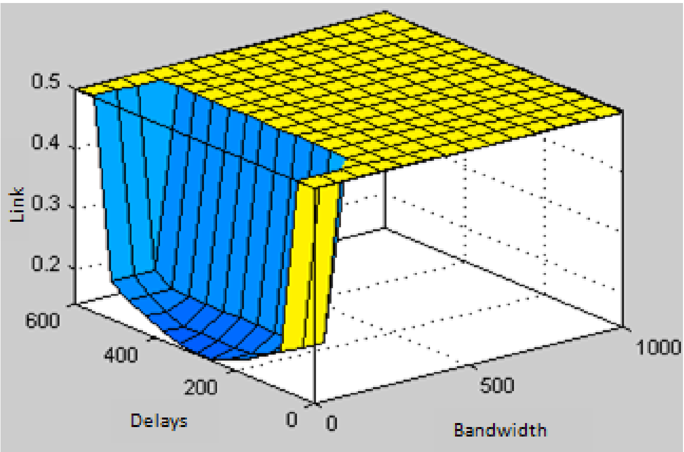
We will compare three methods (COG, MOM and LOM). This can be done better with some examples using 3 D surface viewer in MATLAB.

If we use rule 3 (from rule editor in MATLAB):
Rule 3: *If (bandwidth is High) and (delay is Acceptable) and (loss is Acceptable) then (link optimization is High)*

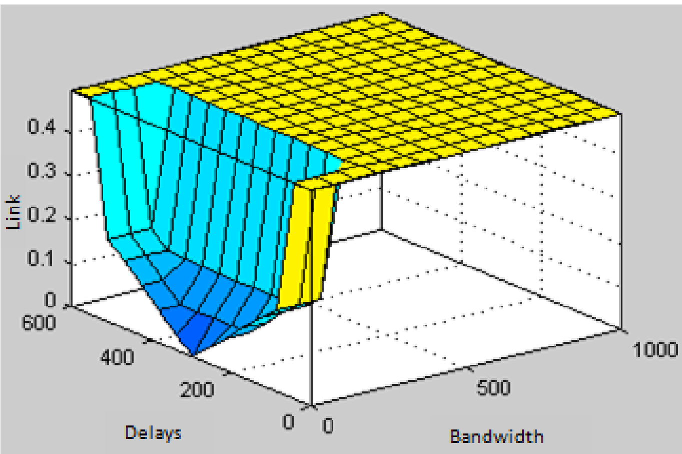
If we take fuzzy values for bandwidth –high (946 Mbps), delays-acceptable (25.3 ms), losses-acceptable (0.63 %), then we will see that link optimization is 86.4 %. We can see this graphically with rule viewer in MATLAB software. From this figure we can clearly see that the link optimization is to high using COG method as defuzzification method. In figure 6 is shown rule viewer for COG method.

Figure 6. Rule viewer for COG method

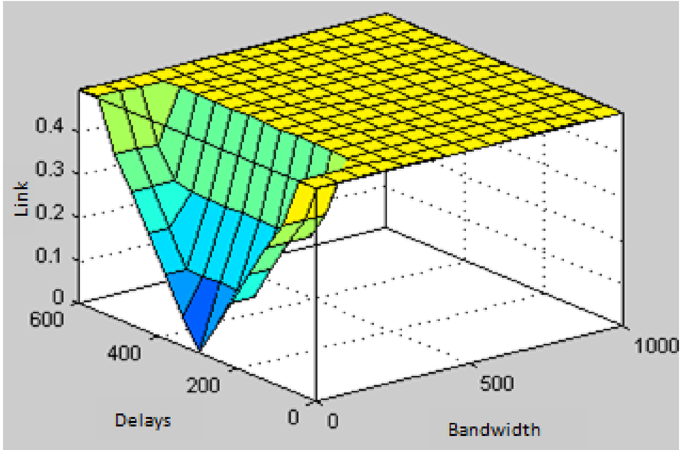
The value 86.4% is the value after defuzzification. Figure 7 shows in 3 D the surface viewer for 3 methods.



a) COG method



b) MOM method



c) LOM method

Figure 7. Surface Viewer in 3D for 3 defuzzification methods: a) COG, b) MOM dhe c) LOM

From the figure above we can see that COG method gives better results, or in other words, link optimization is better using COG method for finding crisp values after defuzzification process.

8 Conclusion

In this paper we have taken into consideration three metrics of MPLS network in order to find better link optimization. For finding a better link optimization we have used intelligent technique-fuzzy logic controller. As input parameters in FLC we have considered MPLS network metrics. One of the main components of FLC is defuzzificator that plays a key role for obtaining output values. In this paper we have used three main defuzzification methods. Also it is made a comparison between three main defuzzification methods through MATLAB software. Analysis made with MATLAB show that COG method is the best one for obtaining better crisp values for link optimization.

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