

## Traffic Engineering and Quality of Experience in MPLS Network by Fuzzy Logic characterization

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### Abstract

This paper proposes a load balancing algorithm using fuzzy logic so that maximum Quality of Experience can be achieved. Avoidance of congestion is one of the major performance objectives of traffic engineering in MPLS networks. Load balancing can prevent the congestion caused due to inefficient allocation of network resources. Another aspect of the network performance is Quality of Experience (QoE). QoE in telecommunications terminology, it is a measurement used to determine how well that network is satisfying the end user's requirements. The Mean Opinion Score (MOS) is an important factor in determining the QoE. MOS is a measurement of the quality delivered by the network based on human perception at the destination end. Specifically we can tell mean opinion score (MOS) provides a numerical indication of the perceived quality of received media after compression and/or transmission.

**Index Terms**—QoE, MPLS, WAN, Virtual Links, LSR, MOS, Absolute Delay, Jitter, LSP

### I. INTRODUCTION

Traffic engineering is a process that enhances overall network utilization by attempting to create a uniform or differentiated distribution of traffic throughout the network. An important result of this process is the avoidance of congestion on any one path. It is important to note that traffic engineering does not necessarily select the shortest path between two devices. It is possible that, for two packet data flows, the packets may traverse completely different paths even though their originating node and the final destination node are the same. This way, the less-exposed or less-used network segments can be used and differentiated services can be provided. In MPLS, traffic engineering is inherently provided using explicitly routed paths. The Label-switched paths (LSPs) are created independently, specifying different paths that are based on user-defined policies. Multi-protocol label switching (MPLS) is a versatile solution to address the problems faced by present-day networks—speed, scalability, quality-of-service (QoS) management and traffic engineering. MPLS has emerged as an elegant solution to meet the bandwidth-management and service requirements for next-generation Internet protocol (IP)-based backbone networks. MPLS addresses issues related to scalability and routing (based on QoS and service quality metrics) and can exist over existing asynchronous transfer mode (ATM) and frame-relay networks.

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network resources. Another aspect of the network performance is Quality of Experience (QoE). QoE in telecommunications terminology, it is a measurement used to determine how well that network is satisfying the end user's requirements. The Mean Opinion Score (MOS) is an important factor in determining the QoE. MOS is a measurement of the quality delivered by the network based on human perception at the destination end. Specifically we can tell mean opinion score (MOS) provides a numerical indication of the perceived quality of received media after compression and/or transmission.

### II. MULTI-PROTOCOL LABEL SWITCHING

In computer networking and telecommunications, Multiprotocol Label Switching (MPLS) refers to a mechanism which directs and transfers data between Wide Area Networks (WANs) nodes with high performance, regardless of the content of the data. MPLS makes it easy to create "virtual links" between nodes on the network, regardless of the protocol of their encapsulated data.

The growing number of computer users on the Internet and intranets, as well as new bandwidth intensive applications such as those incorporating voice and video, are driving the need for guaranteed bandwidth and increased network reliability. The typical frame 8520/and packet-based networks lack the quality of service (QoS) and traffic shaping sophistication of the powerful yet expensive ATM networks. Furthermore, the proliferation of network protocols increases the complexity and reduces network capability and performance. In an effort to

increase throughput, reduce network complexity in ATM networks, and bring advanced bandwidth shaping and QoS capabilities to non-ATM networks, the Internet Engineering Task Force (IETF) created Multiprotocol Label Switching (MPLS). MPLS combines the power of layer 2 switching with the flexibility and intelligence of layer 3 protocols; it operates independently of other network technologies but is fully capable of interoperating with them. MPLS brings non-ATM networks powerful QoS capabilities, the ability to route multiple network technologies (Ethernet, frame relay, ATM) over one infrastructure and the capability of interoperating with modern routing protocols such as RIP, OSPF and BGP, while increasing efficiency and simplifying network infrastructure.

Multiprotocol label switching (MPLS) is a versatile solution to address the problems faced by present-day networks—speed, scalability, quality-of-service (QoS) management and traffic engineering. MPLS has emerged as an elegant solution to meet the bandwidth-management and service requirements for next-generation Internet protocol (IP)-based backbone networks. MPLS addresses issues related to scalability and routing (based on QoS and service quality metrics) and can exist over existing asynchronous transfer mode (ATM) and frame-relay networks. [1] and [2]. The devices that participate in the MPLS protocol mechanisms can be classified into label edge routers (LERs) and label switching routers (LSRs).

An LSR is a high-speed router device in the core of an MPLS network that participates in the establishment of LSPs using the appropriate label signaling protocol and high-speed switching of the data traffic based on the established paths.

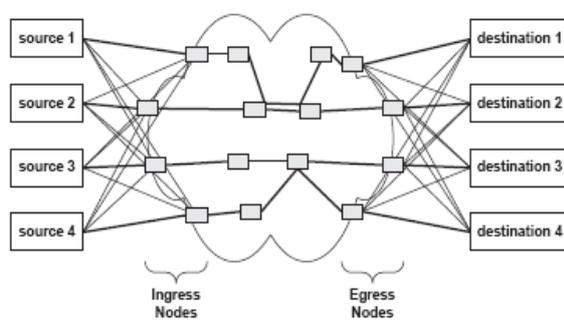


Figure 1: An MPLS Network

An LER is a device that operates at the edge of the access network and MPLS network. LERs support multiple ports connected to dissimilar networks (such as frame relay, ATM, and Ethernet) and forwards this traffic on to the MPLS network after establishing LSPs, using the label signaling protocol at the ingress and distributing the traffic back to the access networks at the egress. The LER plays a very

important role in the assignment and removal of labels, as traffic enters or exits an MPLS network.

### III. TRAFFIC ENGINEERING

It is the process that enhances overall network utilization by attempting to create a uniform or differentiated distribution of traffic throughout the network. An important result of this process is the avoidance of congestion on any one path. It is important to note that traffic engineering does not necessarily select the shortest path between two devices. It is possible that, for two packet data flows, the packets may traverse completely different paths even though their originating node and the final destination node are the same. This way, the less-exposed or less-used network segments can be used and differentiated services can be provided. In MPLS, traffic engineering is inherently provided using explicitly routed paths. The LSPs are created independently, specifying different paths that are based on user-defined policies. However, this may require extensive operator intervention. RSVP and CR-LDP are two possible approaches to supply dynamic traffic engineering and QoS in MPLS. The Current Internet Gateway Protocols (IGP) uses the shortest paths to forward traffic. Using shortest paths conserves network resources, but it causes some resources of the network to be over utilized while the others remain underutilized. The shortest paths from different sources overlap at some links, causing congestion on those links. The traffic from a source to a destination exceeds the capacity of the shortest path, while a longer path between these two routers is under-utilized. The purpose of traffic engineering [3, 4] is to enhance network utilization and to improve the architecture (topology and link capacity) of a network in a systematic way, so that the network is robust, adaptive and easy to operate. An efficient traffic engineering solution shares the data traffic load with the routers, nodes and switches in the network, making none of its individual components either over utilized or underutilized, thus assuring satisfactory service delivery and optimizing resource efficiency.

### IV. QUALITY OF EXPERIENCE

Quality of Experience is often used with Quality of Service terminology are often used interchangeably but are actually two separate concepts. QoE is the overall performance of the system from the point of view of the users. It is the measure of end-to-end performance at the service level from the user perspective and an indication of how well the system meets the user's needs. Quality of Service(QoS) also refers to a set of technologies(QoS mechanism) that enable the network administrator to manage the effects of congestion as well as providing differentiated service to selected network traffic flows

or to selected users. In order to deliver acceptable service quality, QoS targets should be established for each service and be included early on in system design and engineering processes. QoE for the end user is essential and will be a key differentiator with respect to competing service offerings. Subscribers to network services don't care how service quality is achieved. What matters to them is how well a service meets their goals and expectations their Quality of Experience (QoE). To achieve this end, the QoE engineering process involves the following steps.

- Defining the QoE matrices and targets.
- Identify QoE contributing factors and dependencies (delay, jitter and loss).
- Traffic engineering and resource allocation. This involves a control policy for routing, budget allocation etc. In our case we will introduce a load balancing algorithm to optimize the impairments and jitter in order to maximize the QoE.

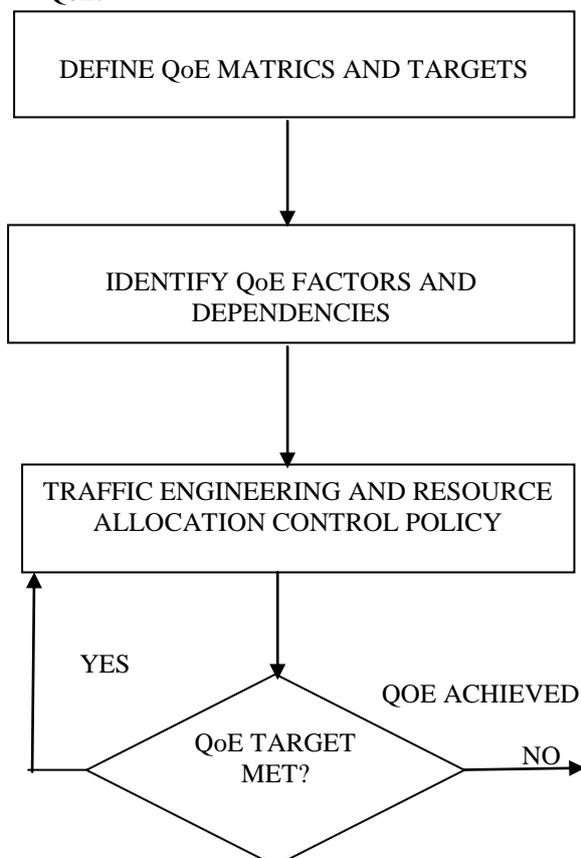


Figure 2: Engineering Process of Quality of Experience

As an important measure of the end-to-end performance at the services level from the user's perspective the QoE is an important metric for the design of systems and engineering processes. This is particularly relevant for video services because bad network performance may highly affect the user's experience, mainly because these services are

compressed and have low entropy. So, when designing systems the expected output, i.e. the expected QoE, is often taken into account also as a system output metric.

This QoE metric is often measured at the end devices and can conceptually be seen as the remaining quality after the distortion introduced during the preparation of the content and the delivery through the network until it reaches the decoder at the end device. There are several elements in the video preparation and delivery chain and some of them may introduce distortion. This causes the degradation of the content and several elements in this chain can be considered as "QoE relevant" for video services. These are the encoding system, transport network, access network, home network and end device.

The concept of QoE in engineering is also known as Perceived Quality of Service (PQoS), in the sense of the QoS as it is finally perceived by the end-user. The evaluation of the PQoS for audiovisual content will provide a user with a range of potential choices, covering the possibilities of low, medium or high quality levels. Moreover the PQoS evaluation gives the service provider and network operator the capability to minimize the storage and network resources by allocating only the resources that are sufficient to maintain a specific level of user satisfaction.

The evaluation of the PQoS is a matter of objective and subjective evaluation procedures, each time taking place after the encoding process (post-encoding evaluation). Subjective quality evaluation processes (PQoS evaluation) require large amount of human resources, establishing it as a time-consuming process. Objective evaluation methods, on the other hand, can provide PQoS evaluation results faster, but require large amount of machine resources and sophisticated apparatus configurations. Towards this, objective evaluation methods are based and make use of multiple metrics

#### IV. A. QUALITY OF EXPERIENCE METRICS

There are two popular methods to access audiovisual quality: Subjective quality assessment and objective quality assessment. Subjective quality assessment means playing a sample audiovisual clips to a number of participants. Their judgment of the quality of the clip is collected and used as a quality metric. Objective quality assessment does not rely on human judgment and involves automated procedures such as signal-to-noise ratio (SNR) measurement of original and reconstructed signals and other sophisticated algorithms such as Mean Square Error (MSE) distortion, Frequency weighted MSE, Segmented SNR and **E-model** to determine quality metrics. The method we are going to adopt in our work is the **E-model**. The problem with Subjective quality assessment techniques is that human

perception of quality is based on individual perception, which can vary significantly between a given set of individuals. The problem with objective quality assessment technique is that they may not necessarily reflect the actual end user experience. In either case the output of these measurements is **MEAN OPINION SCORE (MOS)** which ranks the audiovisual quality on a scale of **1 to 5**. Here our objective is to maximize the MOS which is our metric. The table 1 below shows the audiovisual quality classes for different MOS values [4].

	MOS	USER SATISFACTION
GOOD	4.3 to 5	Very satisfied
	4 to 4.3	Satisfied
ACCEPTABLE	3.6 to 4	Some users dissatisfied
	3.1 to 3.6	Many users dissatisfied
POOR	2.6 to 3.1	Nearly all users dissatisfied
	1 to 2.6	Not recommended

Table 1: Audio Visual Quality Classes

#### IV.B FACTORS AFFECTING QOE

An important aspect in our problem is identifying the network parameters that affect QoE the most and knowing the relative impact of these parameters on the QoE. Extensive studies have been carried out in [4] [5] and [13] where it has been established by objective and subjective experiments on audiovisual traffic, that the variables which affect the MOS ranking the most, are the dynamic network changes caused by route fluctuation, competing traffic and congestion. This network dynamics can be characterized by 3 network metrics namely delay, jitter and loss.

Delay is defined as the amount of time that a packet takes to travel from sender's application to the receiver's destination application. It is recommended by [6] and also verified by [4] [5] that delay bounds for the various grades of perceived performance in terms of Human interaction can be defined as: **GOOD** (0ms -150ms), **ACCEPTABLE** (150ms-300ms), **POOR** (>300ms).

Jitter is defined as the variation in the delay of the packets arriving at the receiving end. It is caused due to congestion at various point in the network, varying packet sizes that result in irregular processing times of the packets and other such factors.

Loss is defined as the percentage of transmitted packet that never reach the intended destination due to deliberately discarded packets or non - deliberately by intermediate links, nodes, and end-systems. It is

suggested that loss more than 1% can severely affect audiovisual quality.

#### V. E-MODEL

The algorithm we will use exploits the E -model as recommended in ITU-T G.107 [6] which returns a value for "Rating factor R" which offers an estimate of the user opinion called the QoE. The E- model is a well established computational model that uses the transmission parameter to predict the subjective quality. It uses a R scale whose value is from 0 to 100 and can be mapped to MOS rankings and user satisfaction as shown in the table 3 [6]

R-value(lower limit)	MOS(lower limit)	User Satisfaction
90	4.34	Very satisfied
80	4.03	Satisfied
70	3.60	Some users dissatisfied
60	3.10	Many users dissatisfied
50	2.58	Nearly all users dissatisfied

Table 2: Relation between R value, MOS and user Satisfaction

The purpose of the model is:

- to predict the subjective effect of combinations of impairments using stored information on the effects of individual impairments
- to help network planners design networks
- to replace hierarchical models and apportionment, which are difficult to apply in a liberalized market

The basic equation for the model is:  $R = R_o - I_s - I_d - I_e + A$

Where:

$R_o$  = Basic signal-to- noise ratio

$I_s$  = Impairments simultaneous to voice signal

$I_d$  = Impairments delayed after voice signal

$I_e$  = Effects of special equipment e.g. codecs

A = Advantage factor (to take account of user advantages such as mobility)

The R factor can be mapped to MOS by the formula,

For  $R > 0$ :  $MOS = 1$

For  $0 < R < 100$ :  $MOS = 1 + 0.035R + R(R-60)(100-R)^7 \cdot 10^{-6}$

For  $R > 100$   $MOS = 4.5$

As this quantity only affects  $I_d$ , the objective function is characterized assuming default values for all other

impairments except  $I_d$  and that leads to the following expression:

$$R = 94 - I_d \quad (1)$$

$$I_d = 25 \left\{ \left( 1 + X^6 \right)^{\frac{1}{6}} - 3 \left( 1 + \left( \frac{X}{3} \right)^6 \right)^{\frac{1}{6}} + 2 \right\} \quad (2)$$

$$X = \frac{\lg \left( \frac{T_a}{100} \right)}{\lg 2} \quad (3)$$

Where  $T_a$  is the delay  
 Assuming the M/M/1 model the average delay is expressed by the following,

$$T_a = \sum_i \left( \frac{\lambda_i}{\lambda_s} \right) / \left( \frac{\mu}{\lambda_i} \right) \quad (4)$$

Where  $i$  is the index number of the  $i$ th LSP operating between the ingress and the egress router.

By substituting (4) and (2) in (1), the rating factor can be characterized as the function of the traffic rate ( $\lambda$ ). The problem is now a maximization problem:

Maximize,

$$f(\lambda) = 94 - 25 \left[ \left( 1 + \left( \left( \log \left( \sum_i \left( \frac{\lambda_i}{\lambda_s} \right) / \left( \mu - \lambda_i \right) / 100 \right) / \log 2 \right) \right)^6 \right)^{\frac{1}{6}} \right]$$

$$- 3 \left[ 1 + \left( \left( \log \left( \sum_i \left( \frac{\lambda_i}{\lambda_s} \right) / \left( \mu - \lambda_i \right) / 100 \right) / \log 2 \right) / 3 \right)^6 \right]^{\frac{1}{6}} + 2 \quad (5)$$

Subject to  $\lambda_s = \sum_i \lambda_i \quad \forall i \in \text{the IE pair}$

And  $\lambda_i \geq 0$

## VI. RESULTS AND DISCUSSIONS

In the simulation process, we tried to compare the graphs and results obtained with the defined standards of ITU-T

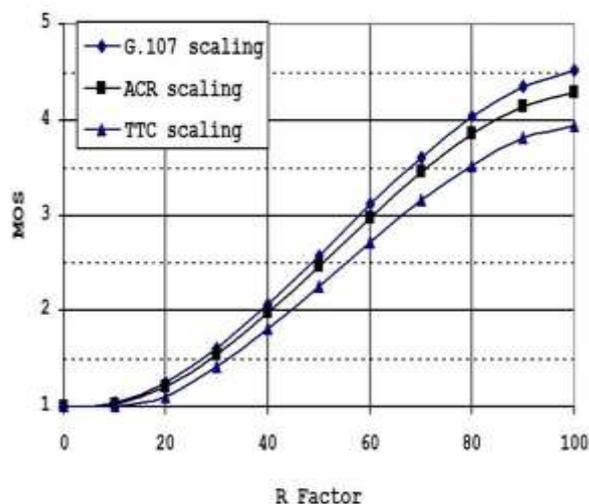


Figure 3: ITU-T G.107 relation between MOS and R

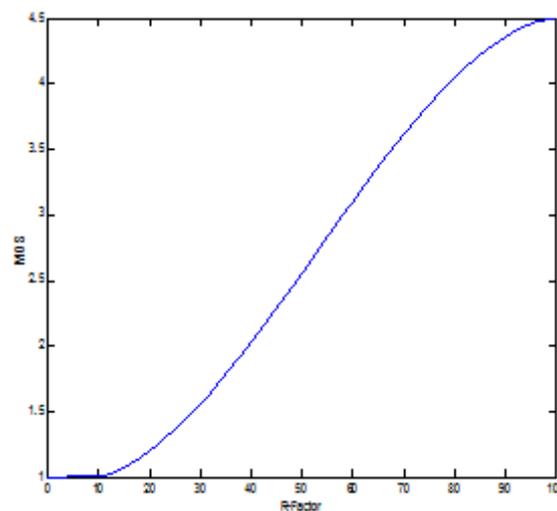


Figure 4: Simulation relation between MOS and R

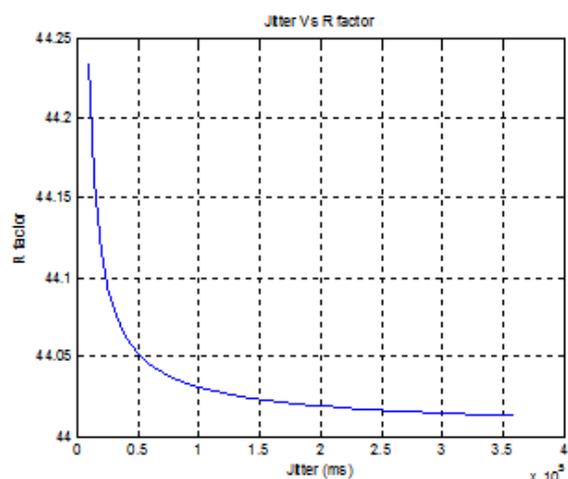


Figure 5: Relation between Absolute Delay and R factor

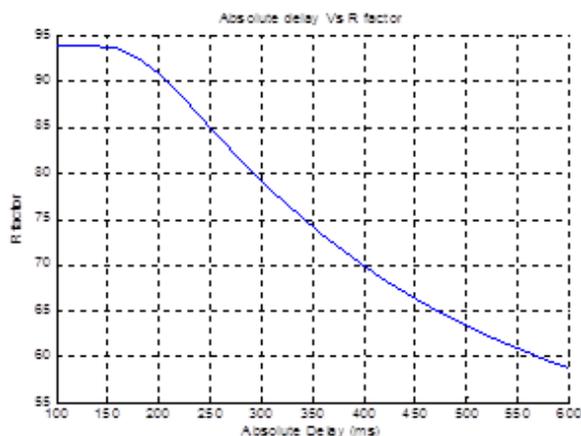


Figure 6: ITU-T Relation between Average Delay and R factor

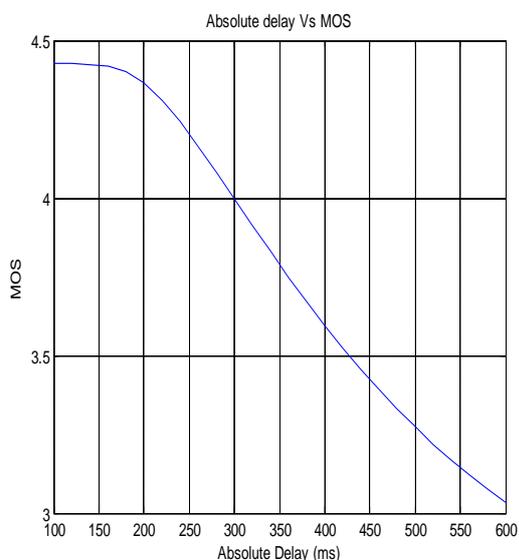


Figure 7: Relation between Absolute Delay and MOS

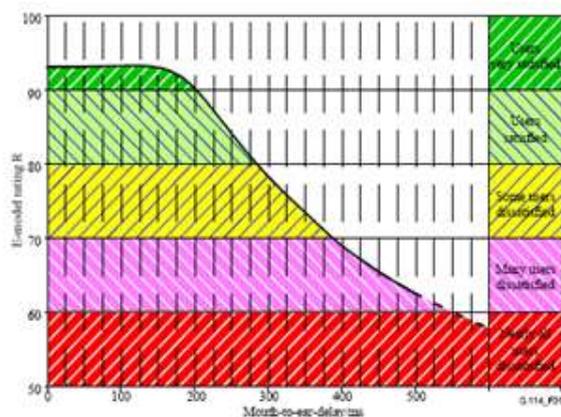


Figure 8: Relation between Jitter and R factor

## VII. CONCLUSION

Since it is difficult to develop as many communication solutions as possible applications, the scientific and technological communities aim towards

providing general services allowing to give to each application or user a set of properties now-a-days called “Quality of Service” (QoS), a terminology lacking a precise definition. This QoS concept takes different forms according to the type of communication service and the aspects which matter for a given application: for performance it comes through specific metrics (delays, jitter, throughput), for dependability it also comes through appropriate metrics: reliability, availability; vulnerability for instance in the case of WAN (Wide Area Network) topologies, etc. At the conclusion we can tell that QoE is a subjective measure of performance in a system. QoE relies on human opinion and differs from quality of service (QoS), which can be precisely measured. For example, a person's reaction to listening to music through headphones is based not only on the frequency response of the system and the speakers, but the comfort of the unit and the individual's hearing sensitivity.

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