Dynamic Sizing of Label Switching Paths in MPLS Networks

Gustavo B. Figueiredo[1] José. Augusto. S. Monteiro[2] Nelson. L. S da Fonseca[1]
Antônio. A. A. Rocha[3]

[1] State University of Campinas
Institute of Computing
[2]Salvador University - UNIFACS
Núcleo Interdepartamental de Pesquisas em Redes de Computadores
[3]Federal University of Rio de Janeiro
COPPE/Sistemas, Computer Science Department

Abstract - **This paper presents a mechanism for the dynamic sizing of Label Switched Paths (LSPs) in MPLS networks based on the mean queue size at the ingress router of the LSP. Upon exceeding the established thresholds, the mechanism is triggered and the LSP is resized after a signaling delay. Results indicate that the lower the threshold is the faster the LSP recover from an unfavorable situation**

I. INTRODUCTION

The Internet is expected to become a carrier for voice, video and data applications. To support the requirements of multimedia applications it is essential to incorporate new technologies into its infrastructure. QoS (Quality of Service) provisioning and resources usage optimization are two essential attributes that these new technologies should have.

The optimized use of resources is a necessary step in order to avoid traffic congestion and degradation of services. Such use is accomplished by traffic engineering that consists of a number of procedures such as traffic measurements, characterization and load balancing.

Multiprotocol Label Switching (MPLS) has been widely recognized as an important traffic engineering tool for IP networks. Such significance is due to two main characteristics. First, the utilization of short, fixed length labels in the process of forwarding datagrams, which results in expressive performance enhancement. Second, its ability to create circuits – known as LSPs (Label Switched Paths) – in networks without connection. These MPLS features enables provisioning, either within the integrated services framework or within the differentiated services framework.

The adequate sizing of LSPs plays a fundamental role in supporting applications which requires QoS guarantees. In networks whose traffic demand is unknown, resource allocation calls for dynamic sizing of LSPs.

This article presents a policy for the dynamic allocation of bandwidth to LSPs so that misallocation can be minimized and also the forwarding of datagrams can be effective even in the presence of network overload.

This work is organized in the following way: Section II presents a brief description of MPLS technology, detailing its main features. Section III shows a model of traffic engineering. Section IV deals with the utilization of MPLS in the process of traffic engineering. Section VI shows the adopted model of simulation, the results obtained from it and their analysis. Section VII brings the work to a conclusion and presents perspectives on its future development.

II. ESTABLISHMENT OF LSP´S

Chief among MPLS (Multiprotocol Label Switching) features are the forwarding of diagrams based on label switching and the utilization of LSPs (Label Switched Paths). Labels are short, fixed length, which have local significance identifiers used to identify paths – or circuits – through which the packets are forwarded. LSPs are the circuits along which packets are forwarded. LSPs can be established in two different ways: hop-by-hop routing and explicit routing.

In the hop-by-hop routing, each LSR (Label Switch Router) selects the next node in isolation based exclusively on local routing information. This way of establishing LSPs can cause congestion, given that all LSPs can be forwarded through the same path when

[1] {gustavo.figueiredo, nfonseca}@ic.unicamp.br
[2] suruagy@unifacs.br
[3] arocha.@ufrj.br

shortest path algorithms are used and the network is overloaded.

In the creation of LSPs with explicit routing, the path is previously selected (usually by the ingress LSR) becoming explicit to all LSRs along the path. One of the advantages of such mode is the possibility to be used for traffic engineering. Upon detecting network congestion, the ingress router of a given flow, can explicitly indicate an alternate route through which all remaining packets should be forwarded. In IP networks it is possible to explicitly choose a route using source routing but it requires the inclusion of the addresses of all routers along the path in the datagram header, generating a high overhead.

Some IP routing protocols operate in a dynamic way. Those based on forwarding equivalence classes (FECs) form LSPs that can be created in two different ways: ordered or independent. In independently created LSPs, each FEC-identifying LSR can pick-up a label without the need for any interaction with a neighbor LSR. In the ordered determination of LSPs, a LSR can assign a label to a FEC either if it is the last node for that FEC or if it has already received a label assignment for this LSP from a downstream LSR.

The establishment of LSPs with ordered control assures certain attributes to these circuits. There is no guarantee for the independent control of LSP that it will be completed by the time it starts receiving packets. Moreover, there is no guarantee that it will not go more than once over the same LSR. Resources reservation is only possible through the ordered control scheme, which can be initiated either by an egress LSR or by an ingress LSR.

III. TRAFFIC ENGINEERING IN MPLS NETWORKS

The best effort nature of the current Internet makes it virtually impossible to provide minimal QoS guarantees for the applications. Furthermore, most routing protocols used in the Internet calculate routes based on shortest path algorithms. This may cause unbalanced resource utilization because links belonging to those paths may be overutilized while other may be underutilized. Moreover, feasible paths are avoided just because they have higher costs. Consequently, multiflows with distinct QoS requirements would probably be forwarded to a path unable to carry them, while a great quantity of links may be underutilized. This is the main motivation for optimizing resources utilization as well as for the adoption of an intelligent network load balancing.

Currently in IP networks, packets are routed at each node based only on the destination address stored at their headers. Packets belonging to distinct applications but with the same source-destination pair may pass through the same path. This brings at least two inconvenient situations. First, the applications packets with different QoS requirements will receive the same treatment, which may compromise the offering of guaranteed QoS for the most demanding QoS ones. Secondly, this forwarding approach produces an uneven utilization of the routes going to the same destination.

Tuning for performance is essential in highly utilized networks. It is essential to use traffic measures, models characterization and control in order to optimize resources utilization. Traffic engineering comprises a finite number of stages. The first stage is the formulation of a control policy, which depends on factors pertaining to the network context such as operational restrictions, costs and criteria for success. The second stage involves the observation of the network conditions by means of its monitoring functions. The third stage is the characterization of traffic and network condition analysis. A number of quantitative and qualitative techniques can be applied at this stage. Thus, it is possible to identify factors that might decrease network performance. Results obtained from this stage can be used for performance optimization, resources allocation, and network redesign. Network performance optimization is the fourth stage. It comes with the application of control procedures leading the network into the desired state in accordance with the control policies. Among the potential control measures that can be employed are the review of network restrictions, modifications in routing-related parameters, setting on traffic management parameters.

It's worthy mentioning that traffic engineering is an adaptable process, implying that the stages described above are recurrent.

The benefits stemming directly from the use of traffic engineering techniques are the capability to avoid congestion points upon forwarding traffic, quick flow re-routing in case of failure, efficient use of the available bandwidth, and QoS.

MPLS has been proposed as a mechanism both for traffic engineering as well as for QoS provisioning. By using MPLS, one can create traffic trunks which are an aggregate of flows belonging to the same FEC. Traffic trunks pass through LSPs which are mapped to the physical structure by routing algorithms based on restrictions according to TT (traffic trunks) attributes and the resources available to the LSPs [10].

IV. A POLICY FOR DYNAMIC LSP RE-SIZING

Adaptability is an essential requirement for the resource allocation subjected to unknown traffic demands. Thus, a policy was proposed to adapt an MPLS network topology as a function of the current load. The proposed policy is based on thresholds which can be function of signaling, switching and bandwidth costs [5].

In the proposed policy, the topological change process is triggered upon the arrival of a bandwidth request for a given LSP. Bandwidth increase and decrease requests are originated by routers when they detect the need for that. Therefore, the problem of resource allocation here is substantially different from the one found in connection-oriented networks in which the traffic demand for a given circuit is previously known.

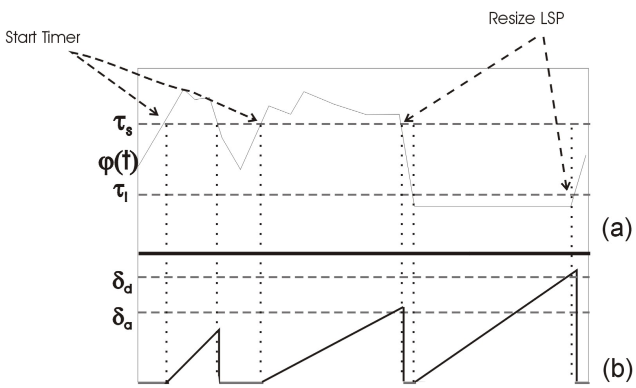

Fig. 1: LSP dynamic resizing mechanism. (a) Queue mean size variation. (b) Timer performance.

The policy makes use of a mechanism based on the peak counter [15] originally proposed as a policing mechanism. The same idea is adopted here to check the mean queue size and the LSPs resizing.

For a given buffer size we would like to allocate enough bandwidth to obtain a desired packet loss rate. At this operational point it is expected that the queue occupancy will fluctuate around the mean value φ for a time interval that do not compromise the desired QoS. The idea is to establish upper (τ_s) and lower (τ_i) thresholds and verify how long the queue length remains respectively above and below those limits by means of a timer. If the queue length remain above the upper threshold for a duration above a tolerance value δ_α, it's a signal that the bandwidth allocated to the LSP is insufficient to keep up with the desired QoS and that, therefore, it should be increased. If the queue length stays below the lower threshold for a period above tolerance δ_d it is a signal that the bandwidth allocated to the LSP is more than the required to warrant the desired QoS and, thus, it can be reduced. The utilization of these timers is necessary to prevent the network from resizing the LSP every time the queue size fluctuate around the thresholds.

This mechanism has five parameters: the upper threshold (τ_s) and the lower thresholds (τ_i), δ_α and δ_d which indicate whether a resizing should or should not be done and φ which is the mean queue size in a given period.

V. SIMULATION MODEL

In order to assess the effectiveness of the proposed policy, simulation experiments were realized. Figure 2 shows the topology used in the simulations. Four ON-OFF sources were employed. The residence time in state ON follows a Pareto distribution. An aggregate of this source type leads to traffic with LRD (Long-Range Dependence) reaching the LSP ingress router. Sources parameters are presented in Table 1 and it corresponds to an average ingress traffic rate in the LSP of roughly 10Mbs.

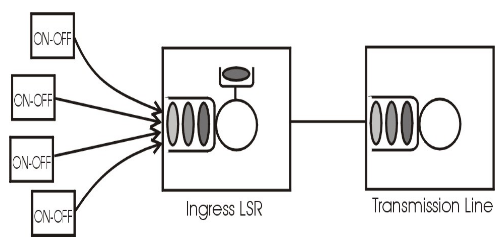

Fig. 3: Simulation model

The first queue in Figure 2 represents the ingress LSR of the LSP used to forward an aggregated flow of packets belonging to a given service class. As described in Section V, this LSR is responsible for regulating the mean queue size of the LSP belonging to the service class in question. The LSP works at a rate slightly lower than the average arrivals rate. High load is expected on the LSP. LSPs band resizing mechanism is evaluated according to this assumptions. The second server represents the transmission in the physical line, which runs at a rate of 20 Mbps. Should a time out occur, a certain amount of band is added to the LSP so that, having a higher service demand, it may be able to decrease the mean queue length and, consequently, reduce the amount of losses.

Table 1. Source parameters

SOURCE	Shape	Scale
Source 1	1.1	1
Source 2	1.3	1
Source 3	1.5	1
Source 4	1.0	1

The mean packets size is 500 bytes, the buffer size is 100KB. The simulation tool used in the simulation experiments was the TANGRAM-II tool [16]. The LSPs are modeled, in the tool, as a Leaky Bucket with an arrival token rate representing the LSP rate as shown in Figure 2. Thus, packets are forwarded only when there is a token in the bucket.

Six cases have been considered. In the first case, the LSP is misdimensioned in relation to the ingress traffic, which has a rate of 6 Mbps. Obviously, this is the characterization of an unstable model, which means that the queue will be always full and losses will increase endlessly, as indicated in Figure 3. This case represents an inadequate allocation statically carried at the beginning of the network operation without the resizing mechanism.

The "over sizing" scenario is also simulated. Over sizing is a common practice among many network operators. For this experiment it was employed a 12 Mbps LSP. As shown in Figure 3, there are no losses. However, a high price is paid since nearly 40% of the band is wasted (Figure 6).

The utilization of dynamic resizing the LSP band was also investigated. The simulation experiments make use of four different values for τ_s and τ_i, which are shown in Table 2. When dealing with band reallocation, we start with an inadequate LSP band of 6 Mbps. However, as described in Section V, upon perceiving a demand above τ_s or under τ_i the LSP is resized.

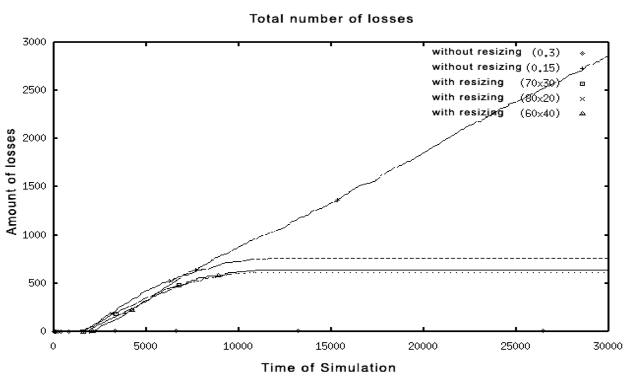

Fig. 1 Total of losses

Figure 3 shows the amount of losses experienced by our target LSP. One can see that the lower the threshold the earlier the adequate sizing is carried out. Losses are eliminated, and the time the network takes to move out from an adverse situation is reduced.

Figure 4 shows the loss rate experienced by the LSP. The period during in which there is an increase in the loss rate corresponds to the period during which the threshold is not reached.

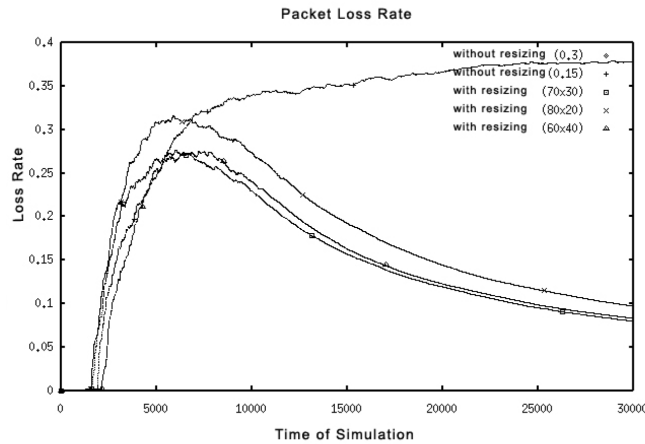

Fig. 4 Loss rate

Since no band reallocation has been performed during this period, and the LSP can't meet the demand, a major part of the job is lost. The decrease occurs after the LSP resizing. One can see that the most expressive decrease in the loss rate occurs when the threshold corresponds to 40% of the buffer size and the least expressive loss rate occurs when the threshold corresponds to 80%. This can also be explained by the fact that the threshold has been reached before the other cases, which eliminates losses. Furthermore, Figure 5 shows that the use of higher thresholds, from 60% to 80% causes the queue size to decrease slowly, leading to higher utilization for a longer period of time, as shown in Figure 6.

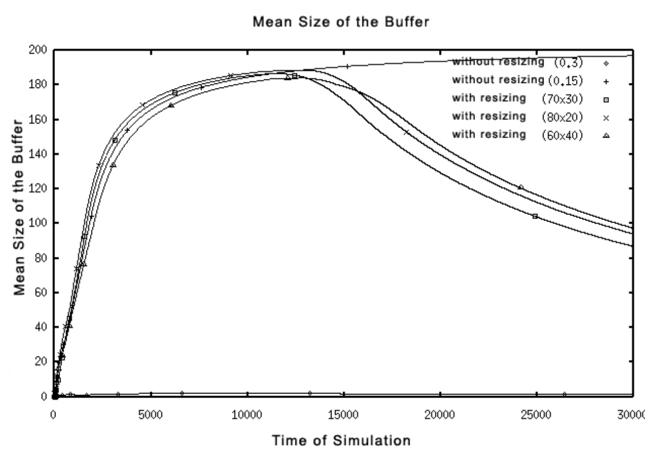

Fig. 5 Mean Size of the Buffer

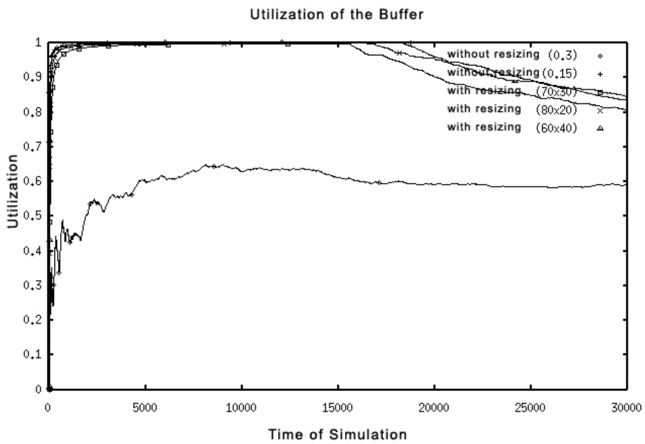

Fig. 6: Utilization of the Buffer

Table 2. Thresholds

CASES	τ_s	τ_I
3	80%	20%
4	70%	30
5	60%	40%
6	40%	20%

VI. CONCLUSIONS

By means of Traffic Engineering (TE), a more balanced distribution of traffic and, consequently, the reduction of congestion occurrence is possible. Owing to its capability to create circuits in IP networks, MPLS has been widely regarded as an important tool in TE. To reach the desired QoS level there should be adequate LSPs sizing

In this article, we have proposed a LSPs dynamic resizing mechanism for MPLS networks, which uses a counter to track the mean queue size. When exceeding the upper threshold resizing of a LSP is triggered. We have shown through the analysis of the ingress router queue, that the lower the upper threshold the easier is the rehabilitation of an unfavorable condition caused by misallocation of bandwidth.

The dynamic resizing of LSPs is a powerful tool for the allocation of band to LSPs where traffic demand is uncertain. Under this condition, the job of allocating resources through conventional methods is ineffective. Dynamic resizing makes the network to enter a stage in which the average loss rate is satisfactory without its LSPs undergoing over dimensioning. As future work the use of measures other than the mean buffer size is suggested.

REFERENCES

[1]. R. Rabbat, K. Abertaux, N. Modi, J.Kenney. *Traffic Engineering Algorithms Using MPLS for Service Differentiation.* IEEE Communications Magazine, pp. 791-795,2000.

[2]. A. Parekh. *A Generalized Processor Sharing Approach to Flow Control in Integrated Services Networks*. PhD Dissertation. MIT, Cambridge, Feb. 1992.

[3]. D. Awduche, *MPLS and Traffic Engineering in IP Networks*. IEEE Communications Magazine, pp. 42-47, Dec. 1999.

[4]. E. Dinan, D. O. Awduche, B. Jabbari. Analytical *Framework for Dynamic Partitioning in MPLS Networks*. In proceedings of the ICC. pp. : 1604-1608. 2000.

[5]. C. Scoglio, T. Anjali, J.C Oliveira, I.F. Akyldiz, G. Uhl. *A New Threshold-Based Policy for Label Switched Paths (LSP) Set-up in MPLS Networks*. ITC17, pp1-12, Dec. 2001.

[6]. M. Kodialam, T. V. Lakshman. *Minimun Interference Routing with Applications to MPLS Traffic Engineering*. INFOCOM, Mar. 2000.

[7]. A. Ewalid, C. Jin, S. Low, I. Widjaja. *MATE: MPLS Adaptative Traffic Engineering*. INFOCOM, Apr. 2001.

[8]. S. Suri, M. Waldvogel, P. R. Warkhed. *Profile-Based Routing: A New Framework for MPLS Traffic Engineering*. Computer Communications. Vol. 25. 2002.

[9]. M. Magalhães, E. Cardozo. *Introdução à Comutação IP por Rótulos Através de MPLS*. In proceedings of the 19th SBRC. May 2001.

[10]. X. Xiao, A. Hannan et al. *Traffic Engineering with MPLS in the Internet*. IEEE Network, Mar/Apr 2000.

[11]. D. Awduche et al. *Requirements for Traffic Engineering Over MPLS*. RFC2702, Sep. 1999.

[12]. E. Rosen, A. Viswanathan, R. Callon. *Multiprotocol Label Switching Archtecture*. RFC 3031, Jan. 2001.

[13]. S. Chen, K. Nahrstedt. *An Overview of Quality of Service Routing for Next-Generation High-Speed Networks: Problems and Solutions*. IEEE Network, pp. 64-79, Nov/Dec 1998.

[14]. M. Garey, D. Johnson. *Computer and Intractability: A Guide to the Theory of NP-Completeness*. New York: W. H. Freeman and Co. 1979.

[15]. J. A. S. Monteiro, M. Gerla, L. Fratta, *Input Rate Control for ATM Networks. ITC13 Queuing Performance and Control in ATM*, pp. 117-122, 1991.

[16]. "Tangram II User´s Manual". http://www.land.ufrj.br/tools/tangram2/tangram2.htm.