Dynamics Sizing of Label Switching Paths in MPLS networks

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Abstract - **This paper presents a mechanism for the dynamic sizing of Label Switched Paths (LSPs) in MPLS networks based on an investigation of the mean queue size at the ingress router of the LSP. Upon exceeding established thresholds, the mechanism is triggered and the LSP is resized after a signaling delay. Through simulations using a self-similar traffic modeled by ON-OFF Pareto sources, the shorter the limit the quicker the LSP recovers from an unfavorable situation.**

I. INTRODUCTION

The enormous growth of Internet users and the need to offer newer, faster, more reliable and more diversified services has a severe impact on its infrastructure at the point that its resources are reaching near scarcity. Furthermore, the Net is expected to become a medium to which will increasingly converge voice, video and data communication. To meet such demanding requirements, besides the expansion of the available resources and enhancements on the existing mechanisms, 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 possess.

Resources usage optimization is a necessary step in order to avoid traffic congestion and the resulting degradation of those services available through the web. It is accomplished by making use of traffic engineering, which consists of a number of procedures such as traffic measurements, characterization and load balancing, ensuing in web performance enhancement.

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 MPLS for QoS provisioning, both in the integrated services framework, (utilizing a RSVP extension to make possible the reservation of resources for the LSPs) and in the differentiated services framework, utilizing the classification and aggregation of microflows that will receive the same treatment in the network being forwarded by the same LSP.

The adequate sizing of LSP adequate sizing plays a fundamental role in supporting applications requiring minimal QoS guarantees. Yet, in networks whose traffic demand is unknown, resource allocation is challenging, resulting in the need for the dynamic and adaptable sizing of LSPs to the traffic to which the network is subjected.

This article presents a policy for the dynamic allocation of bandwidth to LSPs in order that the effects of resource misallocations can be minimized and to offer a good service of datagram forwarding 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 an analysis of them. Section VII brings the work to a conclusion and presents perspectives on its future development.

II. MPLS

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, locally significant 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. Such way of establishing LSPs can cause congestion, considering that all LSPs established in this mode can be forwarded through the same path when shortest path algorithms are used and the network is overloaded.

With explicitly routed LSPs, the path is previously selected (usually by the ingress LSR) becoming explicit to all LSRs along the path, as the very name suggests. One of the advantages of such mode is its ability to be used for traffic engineering. Depending on links conditions, the ingress router of a given flow, upon detecting network congestion, can explicitly indicate an alternative route through which all remaining packets should be forwarded. In conventional IP networks it is already possible to explicitly choose a route using source routing but it requires the inclusion of the addresses of all the routers along the path in the datagram header, generating a large 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 and independent. In independently created LSPs, each FEC-identifying LSR can pick a label without the need for any interaction with a neighbor LSR. In the ordered determination of LSPs, a LSR can only 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, i.e., in the same stream direction .

The establishment of LSPs with ordered control assures certain attributes to these circuits. There are no guarantee for the independent control of LSP establishment that it will be completed by the time it starts receiving packets, nor that it will not go more than once over the same LSR. Resources reservation by an LSP is possible only through the ordered control, which can be initiated either by the egress LSR or by the ingress LSR.

III. TRAFFIC ENGINEERING

Currently, packets crossing IP networks 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 independently from network conditions at a given moment, which brings about at least two inconveniences to multi-service networks. First, the application packets with different QoS requirements will receive the same treatment , which may compromise the guarantee of QoS for demanding applications. Secondly, this forwarding approach produces an uneven utilization of the routes going to the same destination.

Moreover, the tunning for performance is an essential in highly utilized networks with high traffic demand. A number of factors can influence performance: channels capacities, switching element capacities, and congestion.

Therefore, it is indispensable to use traffic measures, models characterization and control in order to optimize resources utilization. Traffic engineering is the task of mapping traffic flow in a transport physical infrastructure aiming at meeting criteria defined by network operation requirements.

The traffic engineering process can be conceived 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 success criteria. 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. The 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 revisions on network restrictions, manipulations of traffic parameters, modifications in routing-related parameters, manipulation on traffic management parameters.

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

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

IV. MPLS AND TRAFFIC ENGINEERING

The nature of the current Internet and the absence of mechanisms capable of avoiding overloads makes it virtually impossible to provide minimal QoS guarantees. Furthermore, most routing protocols used in the Internet such as OSPF calculate the routes based on shortest path algorithms. This may cause unbalanced resource utilization because the 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. That's why it is important to optimize resources utilization as well as and process an intelligent network load balancing, leading to redirecting the flow across alternative paths.

MPLS has been widely proposed in the literature as a helpful 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 [11].

V. DYNAMIC LSP RE-SIZING

Adaptability is an essential requirement for the resource allocation process subjected to unknown traffic demands. Complying with this principle, a policy was proposed to adapt an MPLS network topology based on the current load. This policy is based on thresholds that are function of signaling, switching and bandwidth costs [6].

In this policy, the topological change process is triggered upon the arrival of a bandwidth request for a given LSP. However, MPLS increasing notoriety as a powerful technology for Internet traffic engineering, it's reasonable to think about dynamic and adaptive mechanisms based on current network load without the need for an explicit request from the user to expand bandwidth, which does not occur in IP networks, at least not for its differentiated services. Bandwidth increase and decrease requests are originated by routers when they detect the need to do so. Therefore, the problem of resource allocation becomes, in this context, substantially different from the approach connection-based networks in which the traffic demand for a given circuit is previously known.

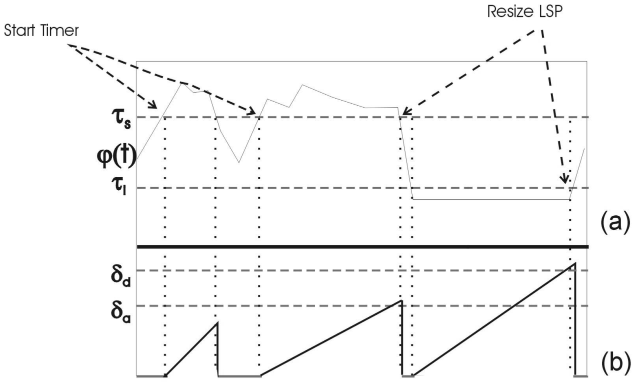

Fig. 1: LSP dynamic resizing mechanism. (a) Queue mean size variation. (b) Timer performance.

The policy proposed here makes use of a mechanism based on the peak counter [16, 18] originally proposed as a traffic policing mechanism. The same idea is adopted so as to check both the mean queue size and the LSPs resizing. A variant of the mechanism is shown in Fig. 1.

For a given buffer maximum length and incoming traffic we would like to ideally allocate to the LSP a bandwidth large enough to obtain a desired quality of service (QoS) expressed in terms of packet loss rate. At this operational point, we can wait the queue occupation to get a value of φ going above and below this mean value and for a time interval which would not compromise the desired QoS. The idea is then to establish upper r (τ_s) and lower (τ_i) thresholds and see how long the queue length remains respectively above and below those limits by means of a timer. Should the queue length remain above the upper threshold for a duration above tolerance 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. Similarly, the permanence of the queue length under the lower threshold for a time length above tolerance δ_d is a signal that the bandwidth allocated to the LSP is above that which is required to warrant the desired QoS and that it can be reduced. The utilization of these timers is necessary so as to prevent the network from resizing the LSP every time the queue size goes above and below the thresholds.

This mechanism has five parameters: the upper threshold (τ_s) and the lower thresholds (τ_i), which signal band increase or decrease, as described above; δ_α and δ_d which indicate whether a resizing should be done or if there is just an eventual traffic increase or decrease; and finally φ which is the mean queue size in a given period of time.

VI. SIMULATION MODEL

Fig. 2 shows the topology used in the simulations. Four ON-OFF sources were employed. The residence time in state ON follows Pareto distribution. Na aggregate of this type of source leads to traffic with LRD (Long-Range Dependence) reaching the LSP ingress router. Sources parameters are presented in Table 1 and model an average ingress traffic rate in the LSP of roughly 10Mbs.

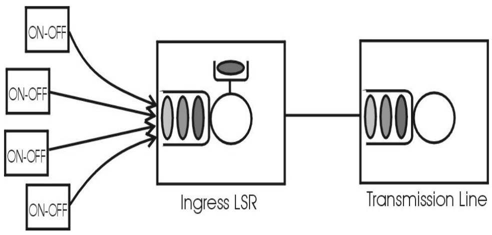

Fig. 2 Simulation Model

The first queue in Fig. 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. This class starts the establishing process (at the beginning of the network operation when there are no established LSPs), characterizing either the establishing of LSPs based on explicit routing, or resizing after expering the the timer which accounts the duration which the mean queue size remains above LSPs acceptable settings.

The LSP works at a rate slightly lower than the average arrivals rate. Therefore, intense traffic is expected in the LSP, and LSPs band resizing mechanism is evaluated according to these 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 bigger service, it may be able to decrease the mean queue length and, by so doing, also 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

Such packets have fixed sizes of 500 bytes, which is a reasonable premise taking into consideration that they are packets of applications belonging to the same service class and, consequently, with very similar requirements. Also, the buffer has a capability of 100KB. Buffer quantity is easily estimated with the expression $\left\lfloor \frac{buffer \quad size}{packet \quad size} \right\rfloor$

For assessing the performance of the mechanism in question, a simulation model was developed making use of the TANGRAM-II tool [17]. The LSPs were modeled, in the tool, as a Leaky Bucket with an arrival token rate representing the LSP rate as shown in Fig. 2. Thus, packets are forwarded only when there is a token in the bucket.

Six cases have been considered: in the first, the LSP is misdimensioned in relation to the ingress traffic, which has a rate of 6Mbps. 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 Fig. 3. This case represents an inadequate allocation carried statically at the beginning of the network operation without the resizing mechanism.

"Over sizing" is another simulated case. This is a technique employed by many network operators. For this situation it was employed a 12 Mbps LSP. As shown in Fig. 3, there are no losses. However, a high price is paid since nearly 40% of the band is wasted (Fig. 6).

The other four cases cover the utilization of dynamic resizing of the LSP band. The simulations make use of four different values for τ_s and τ_i, which are summed up in Table 2. In the cases dealing with band reallocation, analogous to the first case, 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.

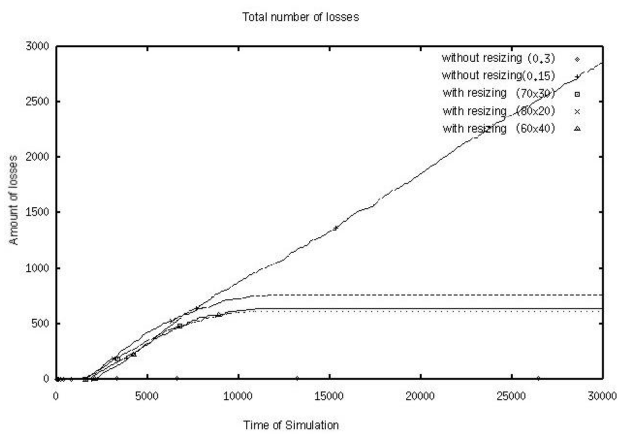

Fig. 3 Total of losses

Fig. 3 shows the amount of losses experienced by our target LSP. One can see that the smaller the threshold the earlier the adequate sizing is carried about, losses are eliminated, and the time the network takes both to get out of an adverse situation and to pass over to a situation capable of offering guarantees in relation to losses is reduced.

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

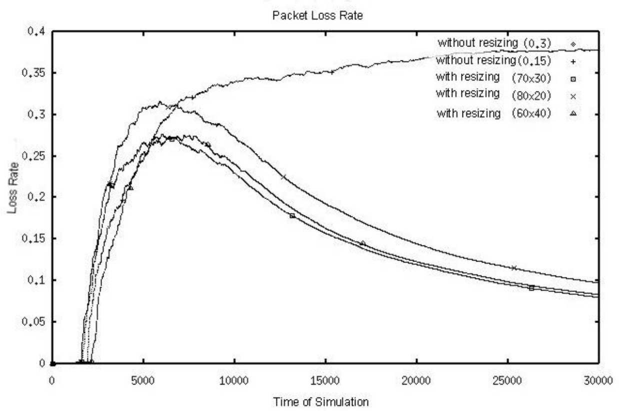

Fig. 4 Loss rate

expressive decrease in the loss rate occurs when the threshold corresponds to 40% of the buffer size and the least expressive loss 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, Fig. 5 shows that the use of higher thresholds, such as 80%, 70% or 60%, causes the queue size to decrease more slowly, what makes the queue to be in maximum utilization for a longer period of time, as indicated in Fig. 6.

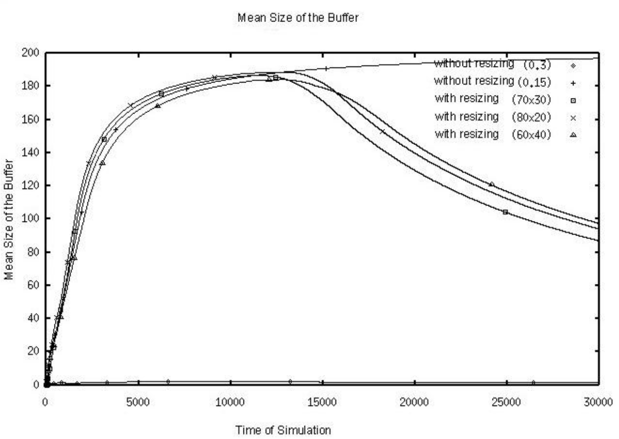

Fig. 5 Mean Size of the Buffer

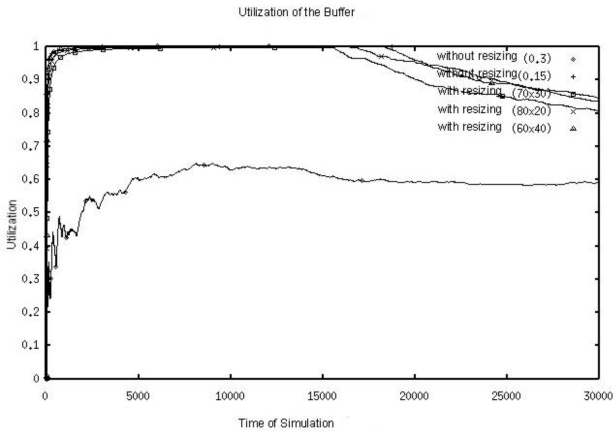

Fig. 6 Utilization of the Buffer

Table 2. Thresholds

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

VII. CONCLUSIONS

By means of Traffic Engineering (TE), a more balanced distribution of traffic and, consequently, the reduction of congestion occurrence is envisioned. Owing to its capability to create circuits in IP networks, MPLS has been widely treasured as an important tool in TE. Yet, to reach the desired QoS level there should be adequate LSPs sizing, which, owing to uncertainties of traffic in the Internet, does not occur always.

In this article, we have attempted to propose an LSPs dynamic resizing mechanism for MPLS networks. Such mechanism makes use of a counter used to measure the mean queue size and can vary between two thresholds, one inferior and another superior, which, if exceeded, can bring about an LSP bandwidth reallocation. We have shown through the analysis of the ingress router queue, by way of simulation, that the shorter the upper threshold the easier the rehabilitation of an unfavorable condition caused by misallocation.

The dynamic resizing of LSPs is a powerful tool for the allocation of band to LSPs where traffic demand is not always known, which makes the job of allocating resources through conventional methods harder. Its use causes 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.

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