Service Differentiation with MPLS

João Neves, Paulo Rogério Pereira, Augusto Casaca
INESC ID, Rua Alves Redol, 9. 1000-029 Lisboa, Portugal.
Phone: +351-213100345. Fax: +351-213145843. Email: {Joao.Neves, Paulo.Pereira, Augusto.Casaca}@inesc-id.pt

I. INTRODUCTION

Offering quality of service (QoS) based on the concept of Differentiated Services has been an important recent concern [1]. This paper describes two kinds of traffic engineering techniques for implementing differentiated services based on Multiprotocol Label Switching (MPLS) constraint based routing (CR-LDP) [2]. Both use dynamic bandwidth allocation schemes and are compared with a fixed bandwidth allocation scheme for the QoS that users get.

The first technique uses an adaptive algorithm that determines a required average throughput per source and adjusts the bandwidth for each path accordingly. The second technique mathematically determines the bandwidth that should be used for each path.

II. NETWORK CONFIGURATION

The network has a core with 12 nodes with at least 5 link-disjoint paths between each pair of core nodes. Additionally, there are 3 ingress routers and 3 egress routers. The core links were configured with 1 Mbit/s capacity and 2 ms delay. Since we only want to study the behavior of the core, the access links have a sufficient large capacity. The Network topology is described in [3]. It was simulated in the NS2 network simulator [4].

Three types of traffic sources were used simultaneously: long lived FTP/TCP sources, constant bit rate (CBR) sources over UDP and Pareto On/Off sources over UDP. Sources are randomly generated with equal proportions of the three traffic types, therefore there might be paths more congested than others in some simulations.

Three traffic classes are defined for service differentiation: Gold, Silver and Bronze. Gold always gets the best QoS, next comes Silver, usually with half of the bandwidth available to Gold. Bronze is a Best-Effort class and gets a small fraction of the available bandwidth along with the unused bandwidth by the other classes.

The Bronze class has no paths reserved through MPLS. For Gold and Silver classes, there are 2 classes x 2 protocols x 3 source nodes x 3 destination nodes = 36 aggregated flows mapped onto MPLS reservations.

III. SIMULATIONS AND RESULTS

A. Fixed Bandwidth

The fixed bandwidth scenario divides the bandwidth along the classes as follows: 30% for Gold UDP, 30% for Gold TCP, 15% for Silver UDP, 15% for Silver TCP, 1% for signaling and 9% for Bronze.

The most interesting scenario is the one where the number of Gold Class sources increases with a fixed number of 6 Silver sources and 60 Bronze sources. This results in a priority inversion between the Gold and Silver classes for high loads, as shown in figure 1.

As the order in which the CR-LDP paths between sources and destinations are created influences the paths chosen, two orderings are used.

The first possibility is to create first the UDP paths for Gold and Silver classes and then the TCP paths for Gold and Silver classes. This will enable that several paths with different source-destination pairs share links in the core.

The second possibility is for all source-destination pairs, no matter what their class or protocol, to use the same path. This will enable a better division of the bandwidth between the different classes.

The first possibility results into a slightly worse delay and jitter for TCP flows, as they use the longest paths. Otherwise, there are no significant differences in the QoS.

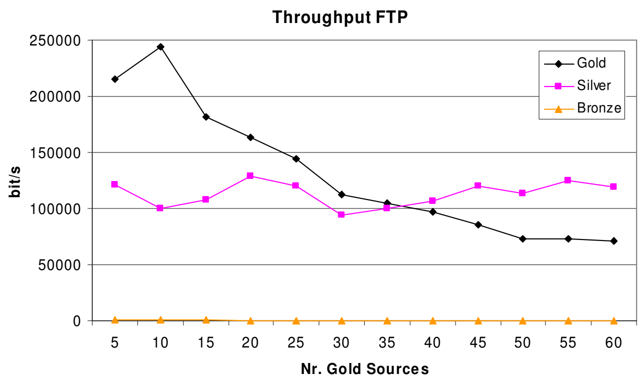

Fig.1 – FTP throughput for fixed bandwidth scenario, using the same links for the same paths

B. Adaptive Dynamic Bandwidth

In the first dynamic technique, an adaptive algorithm divides the bandwidth between the traffic classes.

The throughput per source (TpS) is defined in steps that become lower as the number of sources in a node increase, so as to accommodate them all in the path. When a new source is started, the algorithm analyzes the number of already existing sources and adjusts the new TpS. This is done independently for Gold and Silver classes and for UDP and TCP protocols. If the total bandwidth required for a class (TpS $\times$ number of sources) is higher than what is currently reserved with the CR-LDP, the dynamic algorithm searches in all the links of the path if it is possible to increase the reserve considering the sources of different paths sharing the same links. If possible, the reserve for the path is increased. If not possible, the algorithm will try to decrease the reserves of other paths. The Silver Class is always the first one to be decreased, even if the predefined steps are not respected. The Gold class is only decreased if the TpS allows it. If no decrease is possible, the bandwidth remains unchanged which usually happens with high congestion. For both classes there is always a minimum bandwidth guaranteed considering the number of existing sources.

Figure 2 shows the FTP throughput with this technique for the same situation as in figure 1. Now there is no priority inversion, as the load increases. A certain minimum bandwidth is assured, so the variation is small as the load increases.

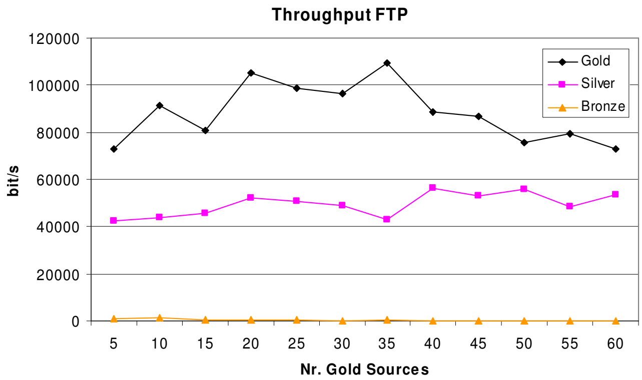

Fig.2 – FTP throughput for the adaptive dynamic technique

C. Mathematical Dynamic Bandwidth

In the second dynamic technique, a mathematical approach to divide the bandwidth among the classes is used. The idea is for the bandwidth per source, which is related to the QoS users get, to be the same in the Gold UDP and TCP classes and the double of Silver classes. The corresponding expressions are:

$$\begin{cases} bwGoldTCP + bwSilverTCP + bwGoldUDP + bwSilverUDP = TOTALbw \\ \dfrac{bwGoldTCP}{NrSourcesTCP} = 2\times\dfrac{bwSilverTCP}{NrSourcesSilverTCP} \\ \dfrac{bwGoldUDP}{NrSourcesGoldUDP} = 2\times\dfrac{bwSilverUDP}{NrSourcesSilverUDP} \\ \dfrac{bwGoldTCP}{NrSourcesGoldTCP} = \dfrac{bwGoldUDP}{NrSourcesGoldUDP} \end{cases}$$

Solving these equations, the bandwidth allocation for each class is obtained as:

$$\begin{cases} bwSilverUDP = \dfrac{TOTALbw \times NrSourcesSilverUDP}{2.NrSrGoldTCP + NrSrSilverTCP + 2.NrSrGoldUDP + NrSrSilverUDP} \\ bwSilverTCP = bwSilverUDP \times \dfrac{NrSourcesSilverTCP}{NrSourcesSilverUDP} \\ bwGoldUDP = 2\times bwSilverUDP \times \dfrac{NrSourcesGoldUDP}{NrSourcesSilverUDP} \\ bwGoldTCP = 2\times bwSilverTCP \times \dfrac{NrourcesGoldTCP}{NrSourcesSilverUDP} \end{cases}$$

Figure 3 shows the FTP throughput obtained with this technique. Now there is a better proportionality between the QoS in the Gold and Silver classes, with an increased throughput for low loads when compared with figure 2.

Figure 4 shows the throughput for Pareto sources. For this case, the proportionality is not so easily obtained, but the Gold class always gets better QoS.

IV. CONCLUSIONS AND FURTHER WORK

The results show that the mathematical technique makes a more uniform division of the bandwidth according to the number of existing sources. The main restriction to this approach is that the paths for the same source-destination pair need to be *always* the same for all the protocols and classes or else, the value for the *TOTALbw,* will not make sense, since it will not correspond to one path but to several ones and the expressions will not work properly.

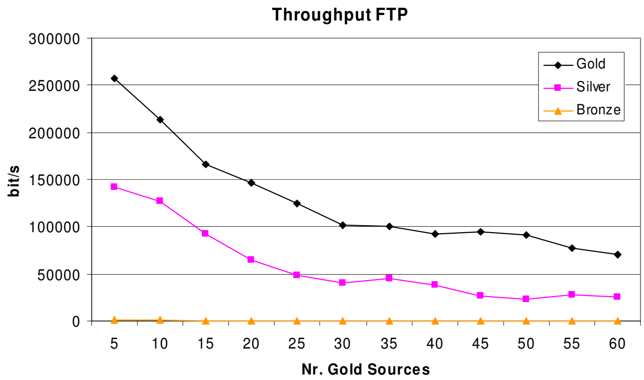

Fig.3 – FTP throughput for the mathematical dynamic technique

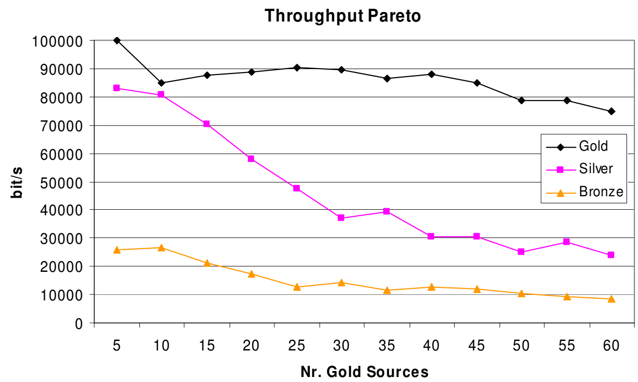

Fig.4 – Pareto throughput for the mathematical dynamic technique

On the other hand, the adaptive algorithm does not have that kind of restrictions and paths can be randomly created. However in these simulations we had a concern which was to put a Gold and a Silver class in the same path in order to make easier for the Gold class to get the needed bandwidth. The results also show that the difference between Gold and Silver is not always proportional, but the aim is to guarantee a TpS according to the number of sources in the path. If the path is equally shared by both classes, Gold flows should usually get twice the QoS Silver flows get.

As regards the signaling traffic required for modifying the bandwidth reserved for the paths, the mathematical technique provides new values for every flow that starts or stops, while the adaptive technique works in steps and requires fewer modifications. The development of a technique to keep the signaling traffic within a certain limit, say 1% of the network capacity, was left for further study.

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