# 8 – Global Analysis of the Simulations

## 8.1 – Overview

After the last two chapters, it is possible to make a global analysis of the results obtained.

In the first section all the improvements brought by the second scenario as compared with the first scenario will be definitively explained.

In the second section a final evaluation of the third scenario will be made: the cases in which it is better and the cases in which it is worse than the first one.

## 8.2 – Second Scenario improvements

As regards the superiority of the second scenario as compared with the first one, there is no doubt.

The results obtained are really good. We can surely say that it is possible to assure with this second scenario:

- Protection between the different classes that means that the excess traffic in one class does not damage the others.
- No packet loss for the UDP packets of the first two classes. This is one of the most important things to assure some quality of service to the real time traffic.
- A UDP rate (Goodput values) that, for the Gold and the Silver class, is exactly that one established in the Service Level Agreement (SLA), that is:
    - 300 Kbit/s per aggregated Gold flow
    - 150 Kbit/s per aggregated Silver flow

- A high improvement in the number of packets received by the best effort traffic (even in the worst case there is an improvement of the 2%)
- Very good results for the UDP Delay:
    - Gold UDP traffic comprehended between 30 ms and 33 ms
    - Silver UDP traffic comprehended between 38 ms and 40 ms
    - Bronze UDP traffic around 55 ms

  The improvements compared with the no-QoS case are:
    - Reduced to one third for the Gold
    - More than halved for the Silver
    - Minimum 30 ms better for the Bronze
- Very good results for the UDP jitter too. As explained in chapter 6, the good results of the first scenario had no practical use because of the great amount of packets lost. Moreover the very good results obtained in all the simulations for all the scenarios should not give many illusions because here we are treating a network that, even if we tried to make similar to a real one, is still distant from the real Internet, where many more different types of traffic sources and paths coexist. But the fundamental reason is that we are only using CBR (constant bit-rate) and FTP traffic that are very regular traffic sources. In the real Internet, there are very irregular traffic sources, like web traffic. These would result in an increased jitter. However, what is important is not the jitter value by itself, but the relative relation among the jitter values.
- Optimum results for the TCP traffic as regards the rate, especially looking at the case of all the UDP traffic overloaded.

Looking at the last two paragraphs in chapter 6, we can say that the total rate values are really close to the ideal expectation that is to fill the average rate per aggregated flow of:

  - 300 Kbit/s for the Gold
  - 150 Kbit/s for the Silver

- A service completely predictable given to the TCP traffic, which is a good feature to help to establish an SLA between the ISP (Internet Service Provider) and the customer
- A significant increase of the total capacity that can be sustained by the network. Arriving, in the case of total UDP overloading, near to the maximum of 9000 Kbit/s established by the theorem of the maximum flow. In particular, looking at tab 8.1, it can be noticed that, calculating the average total value among the first three sets of simulations, the total rate increases by a factor of 2.29 (129%), with a peak value for the UDP increasing factor that reaches 3.35 (235%).

| | Scenario 1 (Kbit/s) | Scenario 2 (Kbit/s) |
|---|---|---|
| TCP | 2369 | 4020 |
| UDP | 1328 | 4444 |
| Total | 3696 | 8464 |
| Increase | | 2,29 |

**Tab 8.1 – Total rate UDP and TCP traffic**

So, it is possible to say that the use of the tools in the second scenario, namely differentiated services and traffic engineering with MPLS Constraint based Routing, are good choices to give a very good service with a high quality.

## 8.3 – Third Scenario improvements

The third scenario has been introduced to give still more quality guarantees to the Gold traffic, in particular for the Gold TCP traffic.

The comparison, like in the previous chapter, will be made only between the second and the third scenario, because here we are looking for improvements relative to the second scenario and the first scenario is worse, as explained before.

After the simulations in the previous chapter, we may say that with the third scenario it is possible to assure to the customers, like with the second scenario:

- Protection between the different classes.
- No packet loss, for the UDP packet of the first two classes.
- Very good values for delay and Jitter.
- A high improvement in the number of packets received by the best effort traffic, UDP and TCP.
- An increment in the total network capacity.

The differences are:

- Regarding the Goodput (that varies dynamically as explained in paragraph 5.6), the total values obtained per class for the Gold UDP class are better or at least equal to the values obtained with the second scenario. So in the third scenario there is always an average Gold UDP rate bigger than in the second scenario.
- The higher values in the rate added to a different traffic engineering (due to the reason explained in paragraph 5.6) brings, as regards the UDP Delay and Jitter, to different, but still very good, values.

  In particular, as regards the Delay:

  - Gold UDP traffic comprehended between 30 ms and 38 ms
  - Silver UDP traffic comprehended between 37 ms and 43 ms
  - Bronze UDP traffic between 52ms and 61 ms

- It is possible to guarantee to the Gold TCP traffic a new service that assures it a bandwidth that is always approximately the double than the Silver bandwidth. This is the greater progress brought by the third scenario.
- The total increment of the total capacity that can be sustained by the network is higher in each simulation, and still nearer to the maximum reachable. Also this is a good improvement of this scenario. Looking at tab 8.2, can be noticed that, as explained in the previous section, calculating the average total value among the first three sets of simulations, the total rate in the third scenario increases still a little by a factor of 1.005 (0,5 %) more than in the second scenario. The value obtained also in this case is near to the maximum of 9000 Kbit/s established by the theorem of the maximum flow.

| | Scenario 1 (Kbit/s) | Scenario 2 (Kbit/s) | Scenario 3 (Kbit/s) |
|---|---|---|---|
| TCP | 2369 | 4020 | 3974 |
| UDP | 1328 | 4444 | 4536 |
| Total | 3696 | 8464 | 8510 |
| Increase | | 2,29 | 1,005 |

**Tab 8.2 - Total rate UDP and TCP traffic**

Doing a deeper analysis regarding the simulations for the TCP varying (paragraph 6.3 and 7.3) it appears that:

- For the Gold TCP traffic, the third scenario is always better (and obviously worse for the Silver traffic) than the second scenario if the number of the TCP Gold sources per aggregated flow is higher than the number of the TCP Silver sources per aggregated flow.
- If the situation is opposite, that is, the number of Silver TCP sources per aggregated flow is higher than the number of Gold TCP sources, then the second scenario is better than the third.

- If the number of sources is about the same, then the situation in the two scenarios is more or less the same.

Therefore, the third scenario is always a good choice as compared with the first scenario. As compared with the second scenario, it is a better alternative. In particular, it is an excellent option if we want to assure a consistent better treatment to the Gold TCP flows as compared with the Silver TCP flows, independently of the load in each of the classes. This behavior is consistent with the better service that Gold users expect, as they pay more than Silver users.

## 8.4 – Future work

To make the network core more similar to the actual network core capacity, a good choice could be to try increasing the core link capacity. Now there are 10Gbps links in use. In the present work, a lower capacity has been chosen only for questions of:

- Simplicity: as the simulations are made with heavy loads, the number of single flows to be monitored should increase proportionally to the link capacity, which would reach a considerable high amount of data for large link capacities. Moreover, an eventual error involving a single flow pattern should be hardly traceable.
- Simulation time: obviously it would increase largely with the link capacity.

However, proportionally, our simulations give a good indication of how a higher capacity core could work.

Another matter could be trying both long-lived and short lived flows, because in this work there are only long-lived flows. This could give more variability and consequently a more real network answers. Also trying other traffic patterns and kinds of traffic (not only FTP and CBR) is a good way to reach this objective.

To verify the results obtained it might be good to try other simulators.

It is possible to choose other ways to offer differentiated services to the customers. For example, in the case of a network with high capacity, a better proportional dynamic assignment of the bandwidth might be found.

Another choice could be trying a number of classes higher than the three that were used: Gold, Silver and Bronze.

We hope that this work represented a good reference for the future work about this field.