

Service Differentiation with MPLS

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Main Purpose

offer QoS based on a concept of Service Differentiation using MPLS

Simulation Scenario

Used the NS2 network simulator program, with the MNS 2.0 patch to implement MPLS capabilities.

Simulated with three types of traffic sources:

- Long lived FTP sources using TCP
- Constant bit rate (CBR) sources using UDP
- Pareto On/off sources using UDP

Three types of traffic classes to make service differentiation:

- **Gold** class – always gets the best QoS
- Silver class – usually gets half the bandwidth of Gold
- **Bronze** class – best-effort class who gets the remaining bandwidth and has no fixed resources

Results express the four main QoS parameters:

Throughput, Delay, Jitter and Loss

Network topology

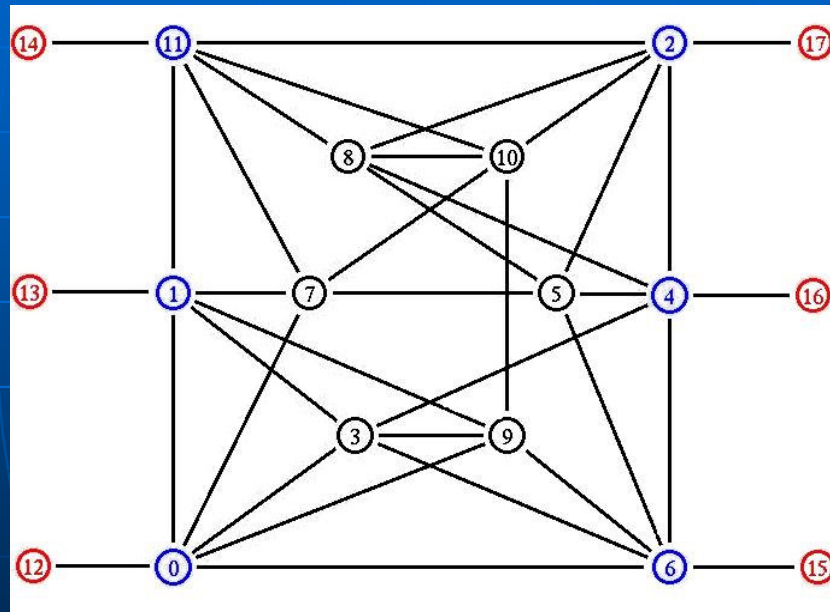
- Core with 12 nodes with at least 5 link-disjoint paths between each pair of core nodes
 - 3 ingress routers and 3 egress routers
- The access network has enough capacity for all traffic: we want to observe the core

Used techniques and simulation scenarios:

- Fixed scenario
Used for comparison

-Adaptive Algorithm

- Mathematical Algorithm



36 aggregated flows for Gold and Silver classes used for reservations using CR-LDP

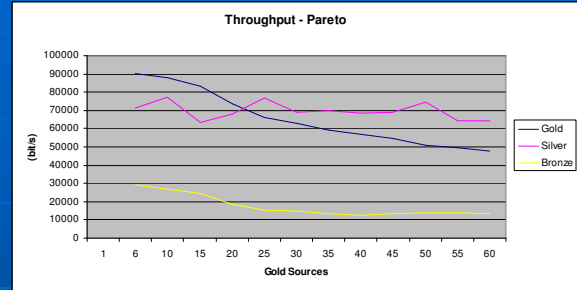
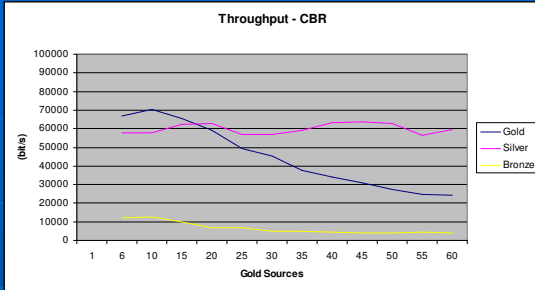
(2 classes x 2 protocols x 3 sources x 3 destinations)

Comparative scenario (Fixed Scenario)

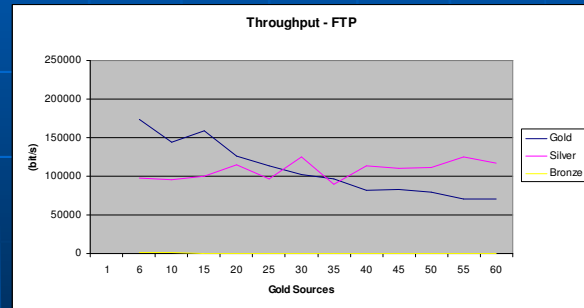
Fixed bandwidth reservation – no changes

- Distribution:
 - 30% for Gold UDP
 - 30% for Gold TCP
 - 15% for Silver UDP
 - 15% for Silver TCP
 - 1% for signaling
 - 9% for Bronze.
- Simulations:
 - All the simulations were made with a number of 60 Bronze sources (to simulate an usual customer)
 - One sort of simulations with Gold sources increasing from 6 to 60. Silver sources with a fix number of 6 sources
 - One sort of simulations with Silver sources increasing from 6 to 60. Gold sources with a fix number of 6 sources
 - One sort of simulations with Gold and Silver sources increasing equally from 6 to 60 sources.

Gold Sources increasing



- Inversion of classes is normal after less than half the number of sources.
- Bronze class gets a small fraction of bandwidth, mainly in the FTP application where the TCP accommodates to the channel



Others:

- Loss for Gold class gets very high at the end (higher than 50%, usually)
- Delay for Bronze class is the smallest in FTP. In other applications is the higher mainly due to queue delay.
- Jitter for Gold and Silver is very similar. Bronze gets a higher jitter.

Adaptive Algorithm

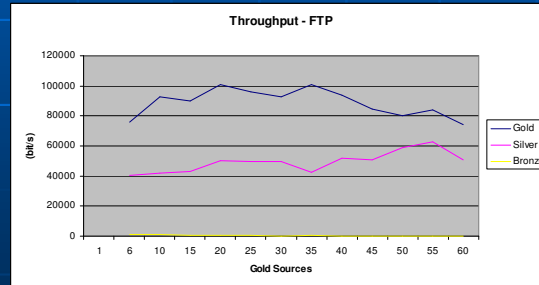
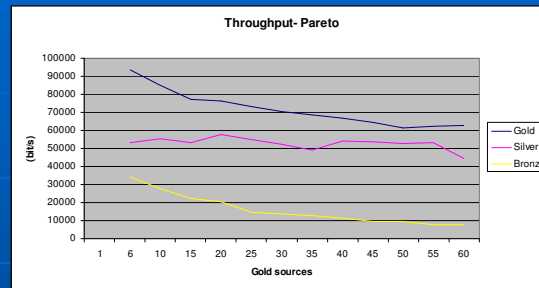
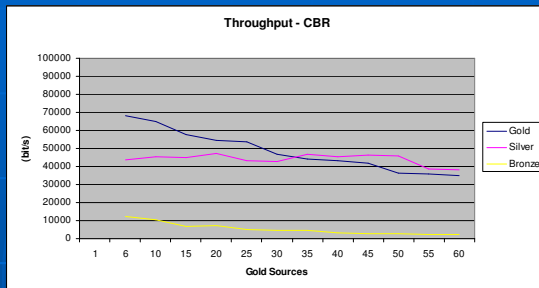
- Defined steps for the throughput per source (TpS) according to the number of existing sources
- Steps become lower when the number of sources increase in order to accommodate them all
- New sources are analyzed independently for Gold and Silver and for TCP and UDP
- When the need for bandwidth exceeds the previously defined, the algorithm analyses all the links of the path in search of available bandwidth
 - If available, changes the value of the reserve
 - If not available, searches for unused bandwidth in other Ispid's or tries to decrease the resources for other Ispid's that share the same links
- Silver class is always the first one to be decreased, even if the pre-defined steps are not respected
- Gold class is only decreased if the steps are still respected
- There is a minimum value to the reserves

Sources	TpS	
	Gold	Silver
>12	25	10
8 to 11	30	15
4 to 9	40	20
<3	50	25

Gold – never decreases; Silver – decreases if necessary
 The functioning of the algorithm is based on a flowchart analysis

Results

Gold increasing



- Inversion of classes doesn't occur (except for a light inversion in CBR)
- The throughput for Silver class is lower
- In FTP scenario, the non-inversion was made with a huge penalty for both classes, compared with the fixed scenario

Others:

- Loss for Gold class becomes always smaller than for Silver class but this one becomes higher
- Delay values aren't much different from the fixed scenario except for Silver class which gets a little more delay
- Jitter doesn't differ much from fixed scenario but Bronze class has a more linear behaviour

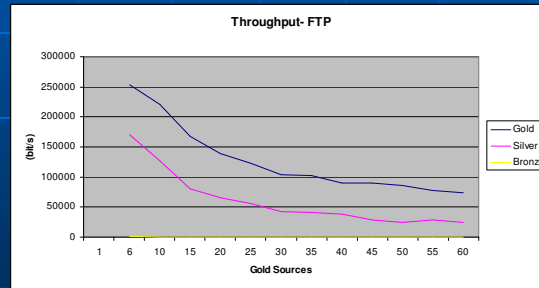
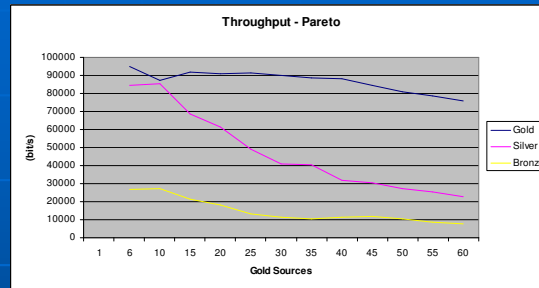
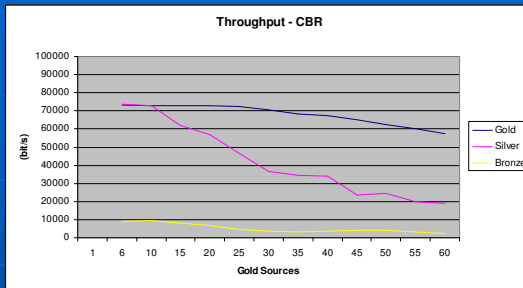
Mathematical Algorithm

- Service differentiation is based on a set of mathematical expressions
- Main principle : Gold gets twice the bandwidth that Silver gets
- The available resources are *always* completely distributed by all classes/protocols
- Certain details are necessary in order to make the algorithm work properly – all the four classes/protocols need to share the same path

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

Results

Gold increasing



-Inversion of classes never occurs

-Gold class always gets, at least, twice the bandwidth Silver gets

-Even in the FTP case, the proportionality is maintained

-There are no limitations to the maximum bandwidth used and, therefore, the maximum throughput it can get

Others:

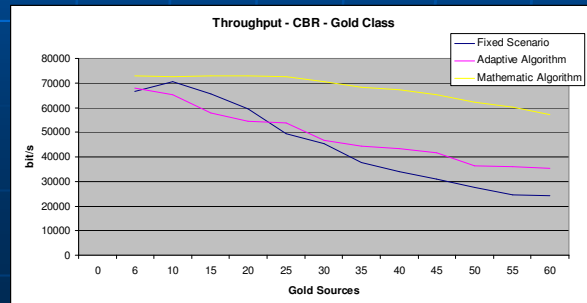
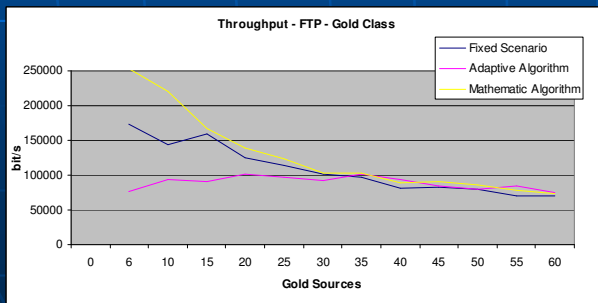
- Loss for Gold class hardly reaches the 20% (much smaller) however Silver class becomes hardly punished
- Delay for Gold class is very similar but Silver class is, once more, very punish, specially in FTP
- Jitter doesn't differ much from fixed scenario but the FTP gets a higher jitter for Silver

Conclusions

- The mathematical algorithm:
 - Makes a better division of the available bandwidth according to the number of sources
 - Never leads to a situation where occurs an inversion of classes
 - Generally gives fair good values in other QoS parameters
 - In order to the algorithm to work properly, all the pairs source-destination *MUST* share the same path
 - A change in the number of one source leads to the change of all the reserves
- The Adaptive Algorithm
 - Usually grants a minimum bandwidth to the flows
 - Accommodates the flows according to predefined steps which become smaller
 - The inversion of classes is not frequent but may occur in some extreme cases
 - The restrictions to the maximum usable bandwidth is frequent, specially in the FTP cases (TCP)
 - The use of the total available bandwidth is not always possible
 - There are no restrictions to the path formation. All the paths are independent from the algorithm perspective.

Conclusions

- The use of a traffic engineering technique to improve the behavior of one or several classes brings advantages
- Not necessary to change the paths – the dynamic change in the reserved bandwidth is enough
- More simple (due to some problems when breaking and restoring a connection)



Annex

Main Purpose

offer QoS based on a concept of Service Differentiation

Option

use an existing network architecture which offers that solution

- **Integrated Services**
- **Differentiated Services**

OR

- **MPLS**
 - Based on label switching
 - Enables traffic engineering methods to make label forwarding and path setup
 - Wide deployment perspective on backbones

Most attractive scenario to implement such kind of service differentiation

Used techniques and simulation scenarios

■ Fixed scenario

- Used only to give a formal term of comparison

■ Adaptive Algorithm

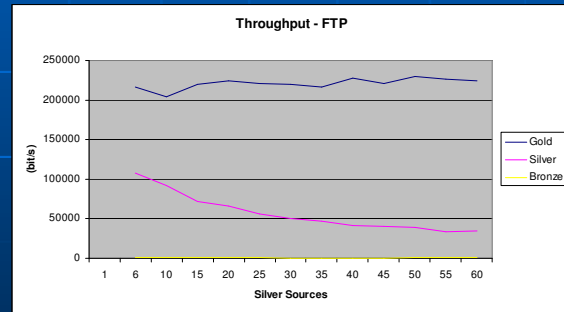
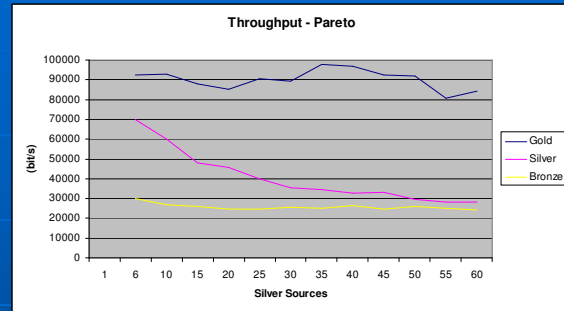
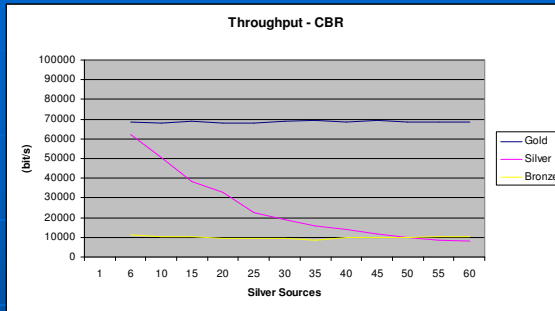
- determines the required average throughput per source and adjusts the bandwidth for each path accordingly
- Takes an intuitive perspective
- Needs an overall view of the network topology and allocated resources

■ Mathematic Algorithm

- Uses a sort of equations to determine the bandwidth for each class/protocol based on the number of sources
- Affects all the resources that share the same pair source-destination

All the scenarios use the CR-LDP
Paths are always created at the beginning.
The only changes are made to the bandwidth

Silver Sources increasing (fixed Scenario)

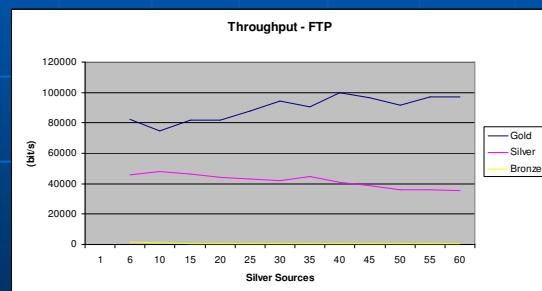
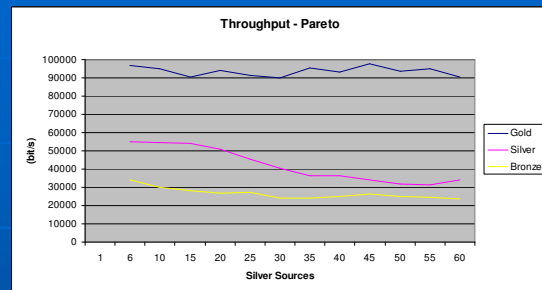
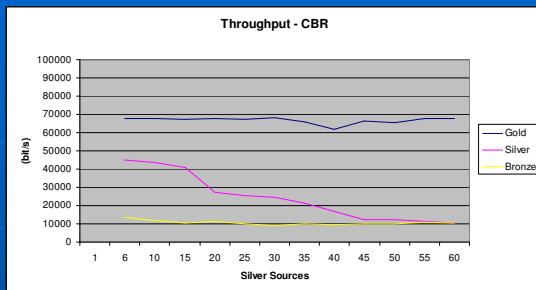


- Inversion of classes doesn't occur but Silver Class almost becomes worse than Bronze at the limit

Others:

- Loss for Silver class gets the same values for Bronze, at the limit.
- Delay for Bronze class is the smallest in FTP, once more. In other applications Bronze and Silver are very similar throughout the simulation
- Jitter for Bronze and Silver are also very similar

Silver increasing (Adaptive Algorithm)

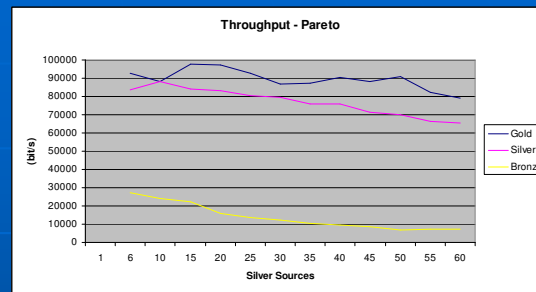
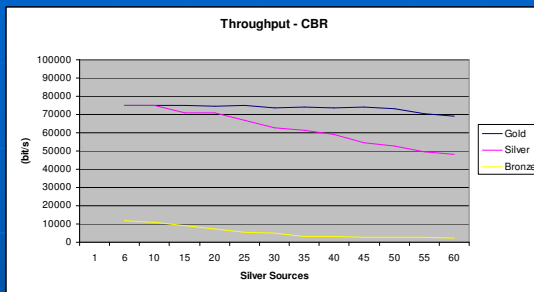


- No substantial differences from fixed scenario except for the FTP where the throughput never goes higher than aprox. 40Kbps but doesn't decrease much from this.

Others:

- No substantial differences in any of the other QoS parameters

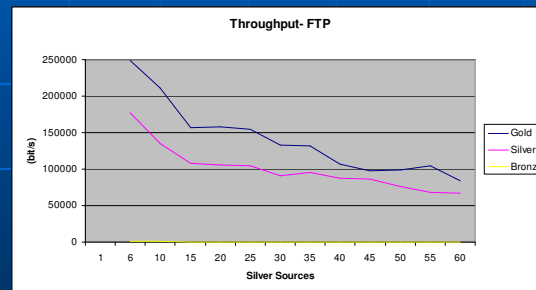
Silver increasing (Mathematical Algorithm)



-Inversion of classes never occurs

-The difference between classes is not so obvious but Silver gets a much better behavior than in the fixed scenario

-Once more, there are no limitations to the maximum throughput it can get (FTP)



Others:

- Loss for Silver class becomes less than two times smaller while Gold keeps low values
- Delay for Silver class is much lower while Bronze becomes a little more higher. Curiously, for FTP, it occurs an inversion at about 20 Silver sources. Gold increases and Silver decreases.
- Jitter also decreases for Silver class and Bronze gets worse

Adaptive Algorithm analysis

- Provides the Service Differentiation but at a price – usually the maximum throughput obtained isn't higher than the obtained in the fixed scenario
- Apart from the bandwidth, Gold class gets more privileges than Silver, namely when it comes to priorities for getting resources from other Ispid's
- There are no requirements for establishing the Ispid paths
- There's always a minimum bandwidth
- Algorithm can get to a point where it isn't possible to redefine the resources

Mathematical Algorithm analysis

- This algorithm complies with the purpose of making Gold with a better service than Silver
- The use of the available bandwidth for reservation purposes is always fully made. No wasted bandwidth
- The remaining parameters, usually, also get a better behaviour
- *All the protocols* and classes that have the same pair source-destination *must have the same path* in order to be possible for the expression to calculate the distribution of resources
- Real time applications might have the same delay that other kind of applications – not always desirable
- Besides, the implementation in a real network might become undesirable once that some nodes may not have all kinds of protocols or classes

Signaling Issues

- Signaling wasn't measured – the MNS 2.0 doesn't provide it.
- Estimated signaling might be higher (avg) in the mathematical algorithm once that a change in one source implies changes in all the other 3 shared sources for that path.
- The adaptive algorithm may have some situations with fewer signaling traffic when changes do not affect other paths.
- Nevertheless, when changes are needed (more traffic) it may affect several other lspid's -> the bandwidth broker must have a on-time map of all the reserves

Future Work

- Development of a technique to keep the signaling traffic within a certain limit
- Integration of both techniques
- Development of the CR-LDP protocol to enable dynamic resource allocation in the NS2 simulator