QoS Prioritization Behavior in an Broadband Hybrid Network

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***Abstract*—A broadband network must have the ability to transport a large amount of information in an efficient way, regardless of the type of service (voice, data, and video). A very good solution for safe and lossless transmission of data from IP access networks was the use of ATM at the core level, packing IP into ATM cells. Nowadays, most ISPs use IP over MPLS, because it allows, through the use of traffic engineering, interconnection with other sections using different switching technologies, and easy application of QoS policies and prioritization.**

***Index Terms*—MPLS traffic engineering; ATM; QoS; different services.**

I. Introduction

MPLS is a technology specifically dedicated to service providers (ISPs). With the implementation of new company-level solutions (IP telephony, storage, wireless connection), the way how traffic passes through networks is being changed, in the sense that the quality of real-time services becomes a critical point for all data networks. Even though ATM networks have been effective over a long period of time in broadband transport networks, the need to manipulate increasing amounts of traffic has made them to be replaced with IP over MPLS solutions [1, 2].

Even if significant service efforts are made by service providers to change high-capacity transport equipment that are outdated by current requirements, such as ATM machines, and migration to modern MPLS-based solutions, the cost of such changes does not allow a sudden migration. Therefore, MPLS has been designed to allow interconnection with network segments that use other data packet processing technologies, thus creating a number of hybrid networks in terms of packet switching.

Nevertheless, the possibility of interconnecting MPLS with ATM, and the use of a hybrid network of this kind, allow network portions where traffic exceeds the capabilities of ATM equipment to be replaced by newer technologies, but when further solutions are not required[3, 4].

II. Proposed Methodology

The purpose of this paper is to present the operation of a high-capacity transport network based on an IP over MPLS infrastructure in the CORE part. It will interconnect a number of customers using different technologies and services. In order to highlight the hybrid character of the implementation, data switching will be performed using different protocols specific to the data link layer, namely Ethernet, MPLS and ATM.

Implementing a CORE of MPLS requires the choice of equipment capable of labeling IP traffic, transporting MPLS traffic resulting from tagging, and allowing the exploitation of specific features. Consequently, we will use the 2800 series CISCO routers for PEs and Ps. The network access part (CE) consists of CE1, CE2 and CE4 customer equipment that are CISCO 1811 routers and make IP over Ethernet switching, and CE3, an ATM segment, that is interconnected with PE1 over Ethernet. This ATM segment, represented by a Nortel 7440 switch, is part of the previous MPLS transport network, currently used as a distribution and access segment for a particular customer.

In Fig. 1 we can see the physical and logical architecture of the network, the type of services that will use and how clients will be transported between remote locations.

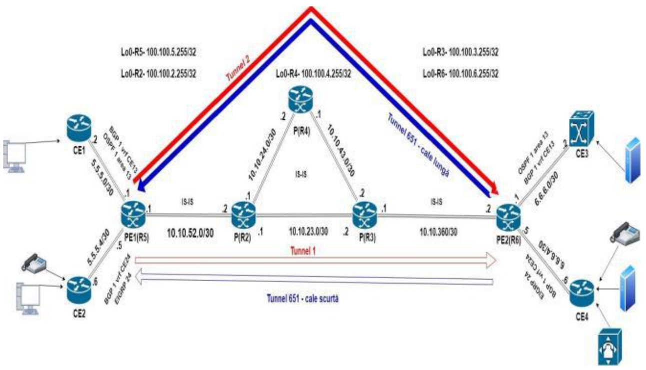

Figure 1. Network topology

For the transport network to work, we need assigning IP address classes, implementing routing mechanisms, and setting up a specific MPLS tag switching protocol.

The routing protocols used are:

- IS-IS for routing and synchronization within the MPLS network (IGP);
- MP-BGP for making the required vpnv4 addresses MPLS-VPN;
- OSPF and EIGRP for packet routing between CEs and PEs and within the ATM network.

MPLS networks require a protocol to switch labels across each segment. For this purpose, having an MPLS-TE implementation, we used RSVP [5].

In real networks for switching and broadband transport, usually in PE nodes there are a large number of different clients, often separated by *vrfs* so as to avoid interaction between them. That is why, for this work, we chose the following scenario:

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- two customers connected in each PE representing the headquarters for two different companies, separated by ***vrfs***;
- the CE3 client is previously switched over by an ATM machine, and then linked to PE2 via an Ethernet interface. This allows us to demonstrate that hybrid broadband switches can be used in real networks;
- CE2 and CE4 customers use prioritized voice traffic and enjoy reserved bandwidth for their services, while CE1-CE3 pair transfers best-effort data with priority 0;
- establishment of two MPLS-TE tunnels with PE1 source and destination in PE2;
- tunnels configured on PE1 calculate routes to PE2 dynamically (see Fig. 2);
- establishing a single tunnel with source in PE2 to PE1 with two routing options;
- the tunnel configured on PE2 will have explicitly declared routes (see Fig. 3).

```
interface Tunnel1
 description Tunel_Priority_mic
 ip unnumbered Loopback0
 tunnel destination 100.100.6.255
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng priority 1 1
 tunnel mpls traffic-eng bandwidth 80000
 tunnel mpls traffic-eng path-option 1 dynamic
 no routing dynamic
!
interface Tunnel2
 ip unnumbered Loopback0
 tunnel destination 100.100.6.255
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng priority 5 5
 tunnel mpls traffic-eng bandwidth 50000
 tunnel mpls traffic-eng path-option 10 dynamic
 no routing dynamic
```

Figure 2. PE1 Tunnels

```
interface Tunnel651
 ip unnumbered Loopback0
 tunnel destination 100.100.5.255
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng priority 1 1
 tunnel mpls traffic-eng bandwidth 80000
 tunnel mpls traffic-eng path-option 1 explicit name cale_scurta
 tunnel mpls traffic-eng path-option 100 explicit name cale_lunga
 no routing dynamic

ip explicit-path name cale_lunga enable
 next-address 10.10.36.1
 next-address 10.10.43.1
 next-address 10.10.24.1
 next-address 10.10.52.1
!
ip explicit-path name cale_scurta enable
 next-address 10.10.36.1
 next-address 10.10.23.1
 next-address 10.10.52.1
```

Figure 3. PE2 Tunnel

As far as the ATM network segment is concerned, it has been configured as follows:

- the access to the client (LAN) and to the PE (WAN) uses an Ethernet card that offers the possibility of interconnection with the access equipment (Laptop) and the PE router;
- ATM switching is done inside the ATM machine, using an OC3 card, connects through an LC-LC optical fiber patch between dedicated machine interfaces;
- routing IP classes, both LAN and WAN linking between ATM and PE1 (MPLS), and those used to communicate between virtual routers is done using the OSPF protocol, as can be seen in Fig. 4;
- in order to be able to make ATM-specific switching based on AALs, two virtual routers were configured on the Nortel 7440;
- the connection between the two virtual routers is an ATM circuit that maps two *atmnpe* interfaces to two *atmif* interfaces, forming a virtual cell-switching circuit L2.

```
d -p vr/test1 pp/* ip log/* ospf

Vr/TEST1 Pp/* IpPort LogicalIf/* OspfIf
   Use -noTabular to see hidden attributes: ptmpmode, multicastFwd, authType,
   pollInt, rtrDeadInt, helloInt and retransInt.
+=================+===============+---------------+------+------+---+-------
|        Pp       |    address    |    areaId     |ifType|snmpAd|rtr|transit
|                 |               |               |      |minSta|Pri| Delay
|                 |               |               |      | tus  |   |seconds
+=================+===============+---------------+------+------+---+-------
|LAN              |192.168.36.1   |0.0.0.13       |broadc|up    |  1|      1
|WAN              |5.5.5.1        |0.0.0.13       |ptmp  |up    |  1|      1

d -p vr/test2 pp/* ip log/* ospf

Vr/TEST2 Pp/* IpPort LogicalIf/* OspfIf
   Use -noTabular to see hidden attributes: ptmpmode, multicastFwd, authType,
   pollInt, rtrDeadInt, helloInt and retransInt.
+=================+===============+---------------+------+------+---+-------
|        Pp       |    address    |    areaId     |ifType|snmpAd|rtr|transit
|                 |               |               |      |minSta|Pri| Delay
|                 |               |               |      | tus  |   |seconds
+=================+===============+---------------+------+------+---+-------
|LAN              |6.6.6.2        |0.0.0.13       |broadc|up    |  1|      1
|WAN              |5.5.5.2        |0.0.0.13       |ptmp  |up    |  1|      1
```

Figure 4. ATM virtual routers OSPF configuration

Data traffic was generated using the iperf3 software, while for the voice part we used two Cisco SPA525G VoIP phones. For the phones to communicate with each other, it was necessary to use a Topex ECV4 PBX connected to the LAN part of the CE4 client.

III. Results

The first step in this paper was the generation of data traffic using iperf3 using 10 parallel sessions between two LANs (laptops) connected between CE3 (ATM) and CE1 customers.

The purpose of this first step is to show that the band used for the data exchange between the two entities is the physical one possible at CORE level by MPLS, as no prioritization and prior reservations are made, as can be seen in the capture in Fig. 5.

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```
[ 16]   8.01-9.00   sec   896 KBytes  7.38 Mbits/sec
[ 18]   8.01-9.00   sec  1.00 MBytes  8.43 Mbits/sec
[ 20]   8.01-9.00   sec  1.25 MBytes  10.5 Mbits/sec
[ 22]   8.01-9.00   sec  1.12 MBytes  9.49 Mbits/sec
[SUM]   8.01-9.00   sec  10.2 MBytes  86.5 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[  4]   9.00-10.01  sec   896 KBytes  7.29 Mbits/sec
[  6]   9.00-10.01  sec  0.00 Bytes  0.00 bits/sec
[  8]   9.00-10.01  sec  1.00 MBytes  8.33 Mbits/sec
[ 10]   9.00-10.01  sec  1.62 MBytes  13.5 Mbits/sec
[ 12]   9.00-10.01  sec  1.75 MBytes  14.6 Mbits/sec
[ 14]   9.00-10.01  sec   896 KBytes  7.29 Mbits/sec
[ 16]   9.00-10.01  sec  1.25 MBytes  10.4 Mbits/sec
[ 18]   9.00-10.01  sec  1.50 MBytes  12.5 Mbits/sec
[ 20]   9.00-10.01  sec   768 KBytes  6.25 Mbits/sec
[ 22]   9.00-10.01  sec  1.38 MBytes  11.5 Mbits/sec
[SUM]   9.00-10.01  sec  11.0 MBytes  91.6 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.01  sec  15.6 MBytes  13.1 Mbits/sec
[  4]   0.00-10.01  sec  15.5 MBytes  13.0 Mbits/sec
[  6]   0.00-10.01  sec  7.25 MBytes  6.07 Mbits/sec
[  6]   0.00-10.01  sec  7.12 MBytes  5.96 Mbits/sec
[  8]   0.00-10.01  sec  10.8 MBytes  9.01 Mbits/sec
[  8]   0.00-10.01  sec  10.5 MBytes  8.81 Mbits/sec
```

Figure 5. All bandwidth is used for CE1-CE3 communication

The next step is to generate data traffic between CE2 and CE4, traffic that comes with a priority set in the precedence field equal to value 2 and which requires a reservation of 60 Mbps. Consequently, as can be seen in Figure 6, even though CE1 and CE3 are an already existing session, once the traffic coming from the CE2-CE4 pair enters the MPLS network, the QoS policies are retained and we see a relatively sudden decrease of the transfer rate to a value of approximately 40 Mbps (available 100Mbps - reserved 60 Mbps = remaining 40 Mbps).

```
[ 16]   8.00-9.01   sec   384 KBytes  3.13 Mbits/sec
[ 18]   8.00-9.01   sec   256 KBytes  2.09 Mbits/sec
[ 20]   8.00-9.01   sec   768 KBytes  6.26 Mbits/sec
[ 22]   8.00-9.01   sec   512 KBytes  4.17 Mbits/sec
[SUM]   8.00-9.01   sec  5.75 MBytes  48.0 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[  4]   9.01-10.01  sec  0.00 Bytes  0.00 bits/sec
[  6]   9.01-10.01  sec  1.00 MBytes  8.34 Mbits/sec
[  8]   9.01-10.01  sec   768 KBytes  6.26 Mbits/sec
[ 10]   9.01-10.01  sec  0.00 Bytes  0.00 bits/sec
[ 12]   9.01-10.01  sec   128 KBytes  1.04 Mbits/sec
[ 14]   9.01-10.01  sec  0.00 Bytes  0.00 bits/sec
[ 16]   9.01-10.01  sec  1.00 MBytes  8.34 Mbits/sec
[ 18]   9.01-10.01  sec  0.00 Bytes  0.00 bits/sec
[ 20]   9.01-10.01  sec  2.12 MBytes  17.7 Mbits/sec
[ 22]   9.01-10.01  sec   512 KBytes  4.17 Mbits/sec
[SUM]   9.01-10.01  sec  5.50 MBytes  45.9 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
```

Figure 6. Decrease of CE1-CE3 transfer rate

Reporting this behavior to the CE 2 and CE routers configuration in Fig. 7, it highlights keeping prioritization and QoS over the MPLS-TE backbone network.

```
!
class-map match-any DATE
 match access-group 102
class-map match-all VOCE
 match access-group 103
!
!
policy-map POL
 class DATE
  set precedence 2
   police 60000000 conform-action transmit  exceed-action drop
 class VOCE
  set precedence 5
   police 60000000 conform-action transmit  exceed-action drop
```

Figure 7. QoS policies on CE2-CE4 routers

The third step is to initiate a phone call between the voice LANs of the CE2 and CE4 routers while the data transfer between CE1-CE3 and CE2-CE4 is enabled. Knowing that the voice will have a higher priority than all other types of traffic, we expect the bandwidth allocated for data transfer between CE1 and CE3 to undergo a further decrease so that the 60 Mbps allocated for data traffic between CE2 and CE4 there are no changes, and at the same time the phone link works to the best parameters. This behavior is reflected in the results obtained in Fig. 8 which shows that data traffic between CE1-CE3 customers occupies the remaining bandwidth (approximately 40 Mbps), and when the call is initiated, it decreases by approximately 10 Mbps.

```
  6]  25.00-26.00  sec   570 KBytes  4.67 Mbits/sec    8   9.84 KBytes
  8]  25.00-26.00  sec   390 KBytes  3.19 Mbits/sec    7   8.44 KBytes
 10]  25.00-26.00  sec   481 KBytes  3.94 Mbits/sec   17   9.84 KBytes
 12]  25.00-26.00  sec   742 KBytes  6.08 Mbits/sec    5   26.7 KBytes
 14]  25.00-26.00  sec   461 KBytes  3.78 Mbits/sec    6   15.5 KBytes
 16]  25.00-26.00  sec   359 KBytes  2.94 Mbits/sec    6   14.1 KBytes
 18]  25.00-26.00  sec   529 KBytes  4.33 Mbits/sec    3   21.1 KBytes
 20]  25.00-26.00  sec   634 KBytes  5.20 Mbits/sec    2   28.1 KBytes
 22]  25.00-26.00  sec   484 KBytes  3.96 Mbits/sec    2   14.1 KBytes
SUM]  25.00-26.00  sec  5.26 MBytes  44.1 Mbits/sec   63
- - - - - - - - - - - - - - - - - - - - - - - - -
  4]  26.00-27.00  sec   789 KBytes  6.46 Mbits/sec    6   18.3 KBytes
  6]  26.00-27.00  sec   366 KBytes  3.00 Mbits/sec    4   18.3 KBytes
  8]  26.00-27.00  sec   290 KBytes  2.37 Mbits/sec    7   11.2 KBytes
 10]  26.00-27.00  sec   378 KBytes  3.10 Mbits/sec    8   5.62 KBytes
 12]  26.00-27.00  sec   505 KBytes  4.14 Mbits/sec   10   11.2 KBytes
 14]  26.00-27.00  sec   501 KBytes  4.10 Mbits/sec    8   12.7 KBytes
 16]  26.00-27.00  sec   529 KBytes  4.33 Mbits/sec    3   23.9 KBytes
 18]  26.00-27.00  sec   741 KBytes  6.07 Mbits/sec    4   23.9 KBytes
 20]  26.00-27.00  sec   568 KBytes  4.65 Mbits/sec   10   9.84 KBytes
 22]  26.00-27.00  sec   390 KBytes  3.19 Mbits/sec   12   7.03 KBytes
SUM]  26.00-27.00  sec  4.94 MBytes  41.4 Mbits/sec   72
- - - - - - - - - - - - - - - - - - - - - - - - -
  4]  27.00-28.00  sec   343 KBytes  2.81 Mbits/sec    8   11.2 KBytes
  6]  27.00-28.00  sec   558 KBytes  4.57 Mbits/sec    7   18.3 KBytes
  8]  27.00-28.00  sec   465 KBytes  3.81 Mbits/sec    3   21.1 KBytes
 10]  27.00-28.00  sec   325 KBytes  2.66 Mbits/sec    7   12.7 KBytes
 12]  27.00-28.00  sec   305 KBytes  2.50 Mbits/sec   10   8.44 KBytes
 14]  27.00-28.00  sec   391 KBytes  3.20 Mbits/sec    6   9.84 KBytes
 16]  27.00-28.00  sec   359 KBytes  2.94 Mbits/sec   12   16.9 KBytes
 18]  27.00-28.00  sec   447 KBytes  3.66 Mbits/sec   11   12.7 KBytes
 20]  27.00-28.00  sec   391 KBytes  3.20 Mbits/sec    4   12.7 KBytes
 22]  27.00-28.00  sec   338 KBytes  2.76 Mbits/sec    5   11.2 KBytes
SUM]  27.00-28.00  sec  3.83 MBytes  32.1 Mbits/sec   73
- - - - - - - - - - - - - - - - - - - - - - - - -
  4]  28.00-29.00  sec   373 KBytes  3.05 Mbits/sec   10   9.84 KBytes
  6]  28.00-29.00  sec   512 KBytes  4.19 Mbits/sec    8   14.1 KBytes
  8]  28.00-29.00  sec   498 KBytes  4.08 Mbits/sec    8   9.84 KBytes
```

Figure 8. Bandwidth CE1-CE3 link when priority traffic enters the network

Regarding allocation of resources at the ATM section, in Fig. 9 we can see how cells are allocated for switching traffic based on AALs. The capture is reported at 100 Mbps traffic.

```
PuTTY (inactive)
272> d atmif/21
AtmIf/21
    adminState = unlocked
    operationalState = enabled
    usageState       = active
    availabilityStatus =
    proceduralStatus   =
    controlStatus      =
    alarmStatus        =
    standbyStatus      = notSet
    unknownStatus      = false
    txCellMemoryUsage  = 0 cells
    txCellMemoryCongestionState = 3
    txCellMemoryThreshold       = 0 : 45056 cells
                                  1 : 40656 cells
                                  2 : 36080 cells
                                  3 : 33792 cells
    txCell                      = 1434113
    txCellClp                   = 1430716
    txCellEfci                  = 0
    txCellDiscard               = 6
```

Figure 9. ATM cell allocation

Labeling and prioritization of data packets from the two areas of the network can be seen in Fig. 10 and Fig. 11, namely that the data transmitted between CE2 and CE4 are of the voice type and maintains the priority of 5 in the EXP field, while the packets transmitted between CE1 and CE3 have entered 0 in the EXP field because QoS policies are not used for this communication.

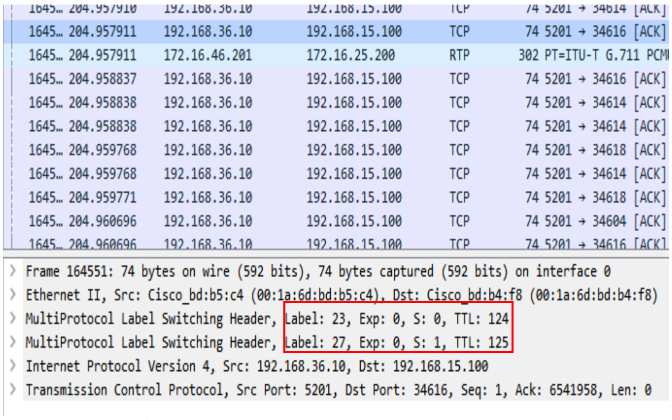

Figure 10. EXP for ATM section

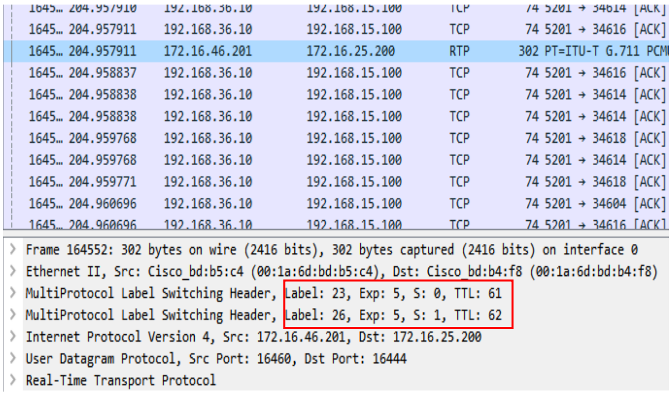

Figure 11. EXP for voice

IV. Conclusions

Conclusions that can be drawn from these tests are that MPLS CORE networks have a great advantage, namely that they are very easy to interconnect with access networks that use QoS policies. Even though ATM equipment allows the use of mechanisms to ensure the quality of services, their use in transport networks and interaction with access networks using QoS is carried out with greater weight.

From the point of view of efficiency when using traffic services in avalanche, MPLS networks have the ability to handle traffic very easily, which is also argued in the literature, which is why ATM networks have been replaced in the ISP with MPLS.

MPLS-TE implementations are very useful when we transport different services, which may require prioritization and preferential treatment. We have shown that such a configuration can be of great help because of the efficiency and ease with which it can take over previously prioritized traffic by customers. It is worth mentioning that a CORE MPLS can receive data from a regular client, as in our case, and from another communications section, such as the ATM distribution network. The behavior will be the same.

Acknowledgement

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References

[1] Luc De Ghein, CCIE No.1897, *MPLS Fundamentals*, Cisco Press, 2007.

[2] *Configuring a Basic MPLS VPN –Multiprotocol Label Switching (MPLS) on Cisco Routers* – Cisco.com.

[3] *Introduction to MPLS* – Steve Smith, Cisco.com, 2003

[4] *Implementing an MPLS VPN over TE Tunnels - MPLS Traffic Engineering DiffServ Configuration Guide*, Cisco IOS XE - Release 3S.

[5] *QoS: RSVP Configuration Guide*, Cisco IOS Release 15M&T.

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