1. Network connection SSSUP-ENSI

1.1 Route analysis

Traceroute from Cristal Laboratory/ENSI to Ircphonet/SSSUP

```
 1     1 ms     1 ms     1 ms   196.203.126.1
 2    25 ms    34 ms    17 ms   10.10.200.5
 3    13 ms    13 ms    12 ms   196.203.125.254
 4    12 ms    13 ms    13 ms   196.203.127.1
 5    21 ms    34 ms    24 ms   rfr.it1.it3.eumedconnect.net [83.97.90.9]
 6    47 ms    46 ms    47 ms   eumedconnect.it1.it.geant.net [83.97.90.2]
 7    48 ms    46 ms    66 ms   garr-gw.it1.it.geant.net [62.40.103.190]
 8    47 ms    46 ms    46 ms   rt1-mi1-rt-mi2.mi2.garr.net [193.206.134.190]
 9    49 ms    49 ms    49 ms   rt-mi2-rt-to1.to1.garr.net [193.206.134.42]
10    56 ms    53 ms    53 ms   rt-to1-rt-pi1.pi1.garr.net [193.206.134.74]
11    58 ms    59 ms    58 ms   rt-pi1-ru-sssup.pi1.garr.net [193.206.136.46]
12     *         *        *     D,lai d'attente de la demande d,pass,.
13    63 ms    61 ms    68 ms   193.205.83.101
```

Traceroute from Ircphonet/SSSUP to Cristal Laboratory/ENSI

```
 1    <1 ms    <1 ms    <1 ms   10.30.2.1
 2    <1 ms    <1 ms    <1 ms   10.30.127.5
 3     6 ms     6 ms     6 ms   10.30.127.1
 4     7 ms    12 ms    43 ms   ru-sssup-rt-pi1.pi1.garr.net [193.206.136.45]
 5    13 ms    12 ms    18 ms   rt-pi1-rt-to1.to1.garr.net [193.206.134.73]
 6    19 ms    17 ms    17 ms   rt-to1-rt-mi2.mi2.garr.net [193.206.134.41]
 7    15 ms    14 ms    20 ms   rt-mi2-rt1-mi1.mi1.garr.net [193.206.134.189]
 8    13 ms    17 ms    17 ms   garr.it1.it.geant.net [62.40.103.189]
 9    48 ms    43 ms    42 ms   geant.it1.it3.eumedconnect.net [83.97.90.1]
10    52 ms    51 ms    52 ms   rfr-gw.it1.it3.eumedconnect.net [83.97.90.10]
11   177 ms    79 ms    82 ms   196.203.127.2
12    57 ms    52 ms    52 ms   196.203.126.9
```

Traceroute analysis shows that the following networks are traversed:
Eumedconnect, Géant, Garr, SSSUP (Fig. 1.1 and 1.2).

In particular:
- ENSI (Tn) – CCK POP Kasbah (Tn) (@ 1 Mbps)
- CCK POP Kasbah (Tn) – POP ATI Tunisi (Tn) (@100 Mbps)
- POP ATI Tunisi (Tn) (@100 Mbps) - POP Eumedconnect Catania (It) (@ 45 Mbps)
- POP Eumedconnect Catania (It) – POP Géant Milan (It) (@155 Mbps)
- POP Géant Milan (It) – POP Garr Milan1 (It) (@10 Gbps)
- POP Garr Milan1 (It) – POP Garr Milan2 (It) (@10 Gbps)
- POP Garr Milan2 (It) - POP Garr Torino (It) (@2.5 Gbps)
- POP Garr Torino (It) - POP Garr Pisa (It) (@2.5 Gbps)
- POP Garr Pisa(It) – SSSUP Central Office (Pisa, @100 Mbps)
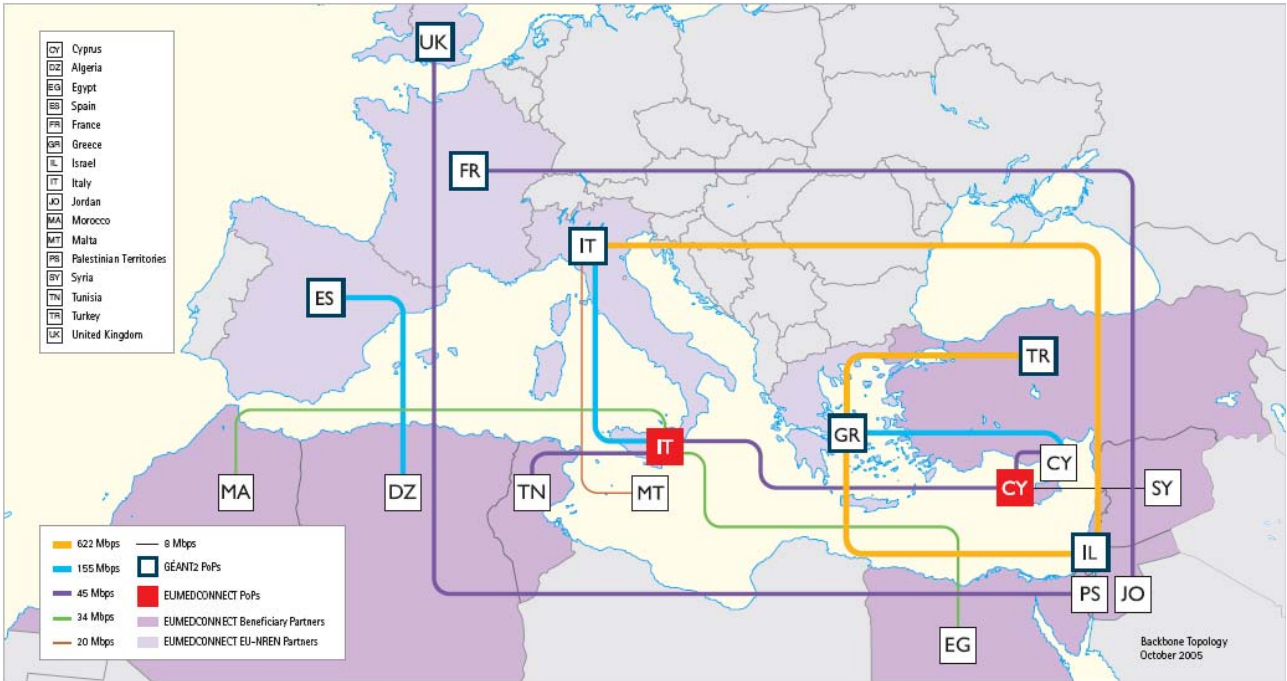- SSSUP Central Office (Pisa) – SSSUP Ircphonet (Pisa) (@1 Gbps)

Fig. 1.1: The EUMEDCONNECT network (http://www.eumedconnect.net/)

Fig.1.2: The GARR Network (http://www.garr.it/)

A preliminary analysis on the traffic statistics of the aforementioned connections has been conducted. The traversed Garr and Géant connections typically show high bandwidth availability. Fig. 1.3 shows an example of the analyzed MTRG (Multi Router Traffic Grapher, www.mtrg.org) traffic statistics. In particular the 10Gbps Garr-Géant connection is considered. The link is extremely underutilized.

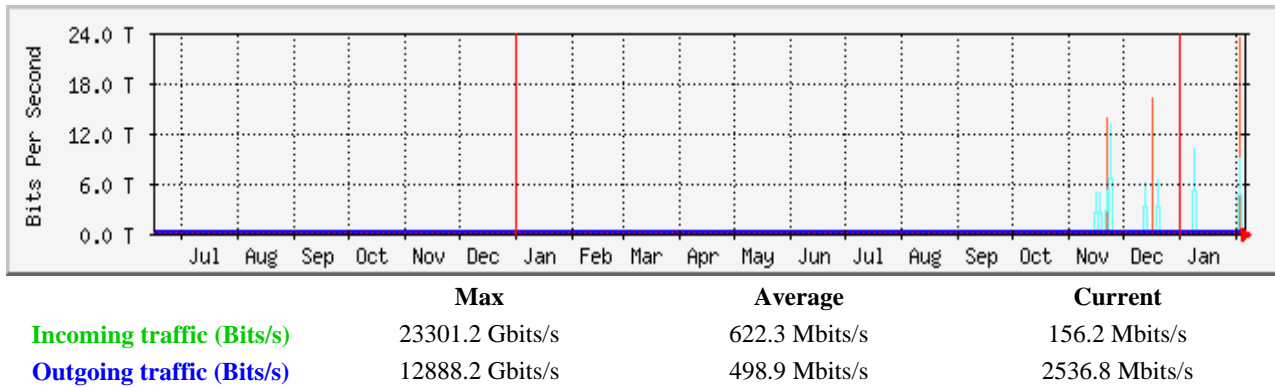|	Max	Average	Current
Incoming traffic (Bits/s)	23301.2 Gbits/s	622.3 Mbits/s	156.2 Mbits/s
Outgoing traffic (Bits/s)	12888.2 Gbits/s	498.9 Mbits/s	2536.8 Mbits/s

Fig. 1.3: MTRG traffic statistics of the 10Gbps Garr-Géant connection
(http://www.noc.garr.it/mrtg/RT.PI1.garr.net/RT.PI1.garr.net.html)

Fig. 1.4 shows the MTRG traffic statistics of the network connection between the Garr POP located in Pisa and SSSUP Central Office. Only the 'daily' statistics are reported since the network connection has been recently reconfigured.

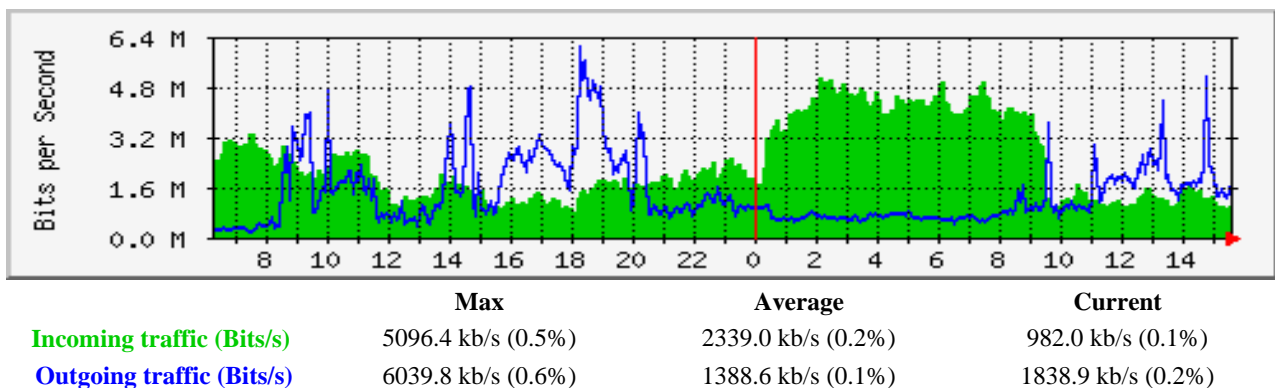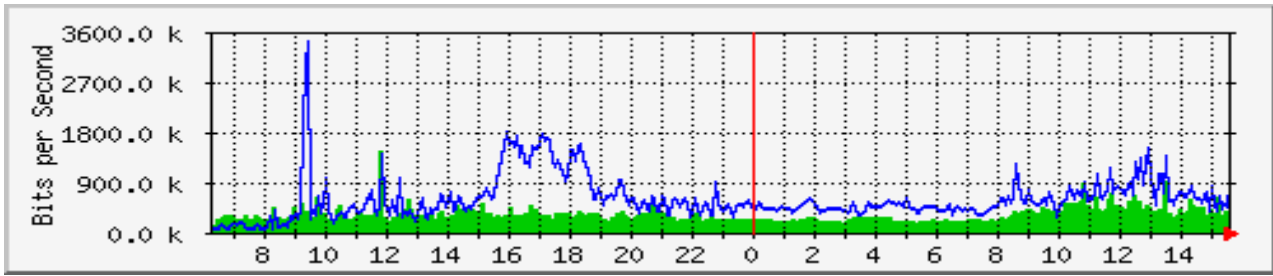|	Max	Average	Current
Incoming traffic (Bits/s)	5096.4 kb/s (0.5%)	2339.0 kb/s (0.2%)	982.0 kb/s (0.1%)
Outgoing traffic (Bits/s)	6039.8 kb/s (0.6%)	1388.6 kb/s (0.1%)	1838.9 kb/s (0.2%)

Fig. 1.4: MTRG traffic statistics of the Garr-SSSUP(Central Office) connection
([Router Sede]VLAN s.cataldo-link, http://www.sss/csi/mrtg/sssupr.sssup.it_6_1.html)

Fig. 1.5 shows the traffic statistics between the SSSUP (Central Office) and SSSUP (Ircphonet).

	Max	Average	Current
Incoming traffic (Bits/s)	1469.4 kb/s (0.1%)	307.1 kb/s (0.0%)	356.0 kb/s (0.0%)
Outgoing traffic (Bits/s)	3417.0 kb/s (0.3%)	588.1 kb/s (0.1%)	793.0 kb/s (0.1%)

Fig. 1.5: MTRG traffic statistics of the SSSUP(Central Office)-SSSUP(Ircphonet) connection
([S.Cataldo]Summit1i-Port 1 -- Summit1i, http://www.sss/csi/mrtg/10.30.127.2_1_1.html)

The network topology between the Eumedconnect POP and ENSI is shown in Fig. 1.6. Two Fast Ethernet connections are available between CCK el Kasba and the Tunisian Internet Agency (ATI): one to carry traffic from and to Eumedconnect network (blue arrow), the other to carry traffic from and to commercial Internet (red arrow). Connection between ENSI and SSSUP can be made through commercial internet (red arrows) or through Eumedconnect network (blue arrows). Tests have shown that the second option is utilized.
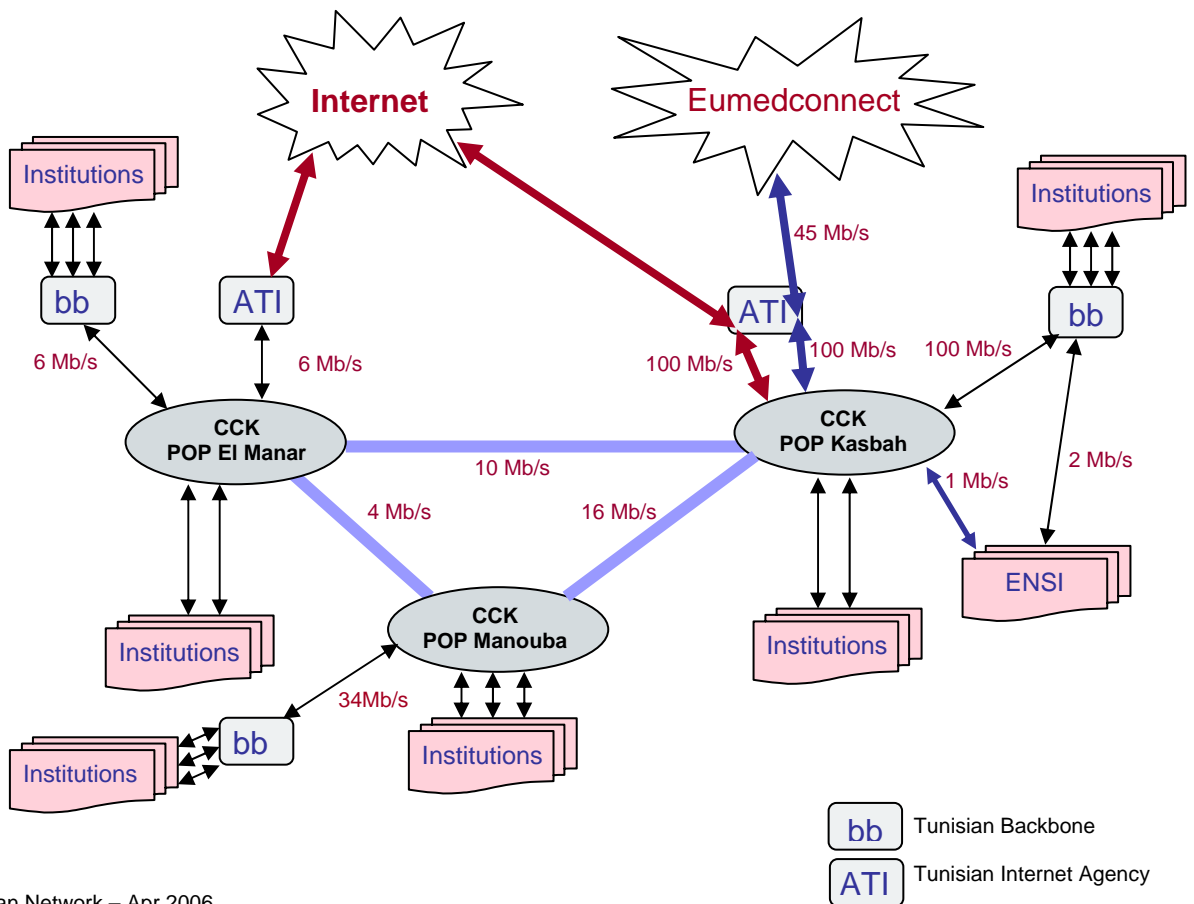
Fig. 1.6: Tunisian network topology.

Fig. 1.7 shows the MRTG statistics for the link between CCK Kasba and ATI used for Eumedconnect traffic: the link isn't heavily loaded. Vice versa, Fig. 1.8 and 1.9 show that the link between ENSI and Kasba is saturated mainly during working hours.
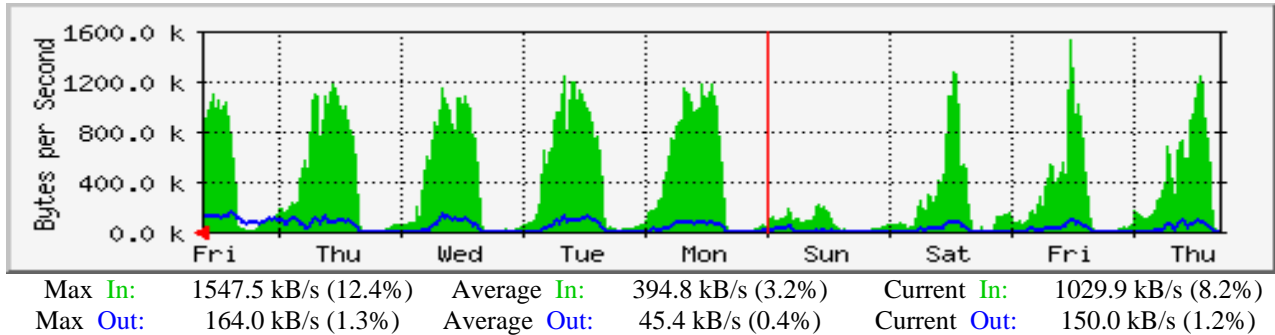

| Max In: | 1547.5 kB/s (12.4%) | Average In: | 394.8 kB/s (3.2%) | Current In: | 1029.9 kB/s (8.2%) |
| Max Out: | 164.0 kB/s (1.3%) | Average Out: | 45.4 kB/s (0.4%) | Current Out: | 150.0 kB/s (1.2%) |

Fig. 1.7: Connection between CCK Kasba and ATI (link used for Eumedconnect traffic). The statistics were last updated Friday, 7 April 2006 at 15:24.
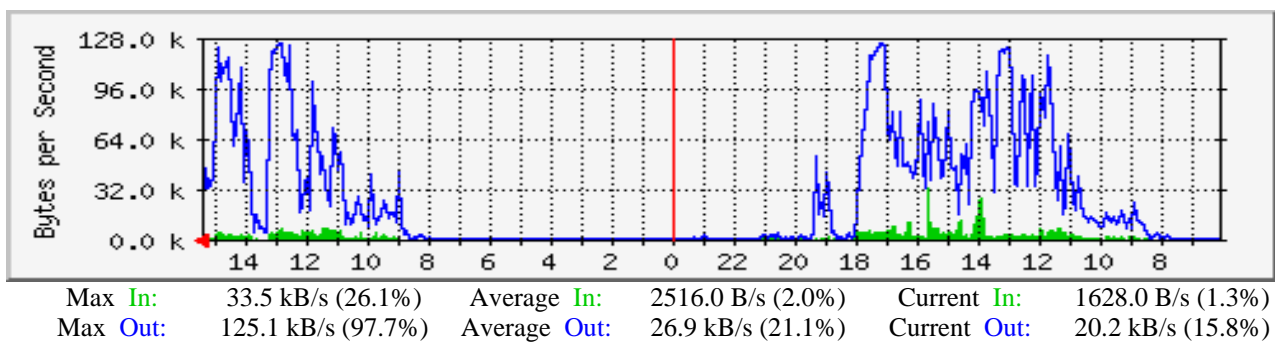

| Max In: | 33.5 kB/s (26.1%) | Average In: | 2516.0 B/s (2.0%) | Current In: | 1628.0 B/s (1.3%) |
| Max Out: | 125.1 kB/s (97.7%) | Average Out: | 26.9 kB/s (21.1%) | Current Out: | 20.2 kB/s (15.8%) |

Fig. 1.8: 'Daily graph' statistics of the connection between ENSI and CCK Kasba. The statistics were last updated Friday, 7 April 2006 at 15:25.

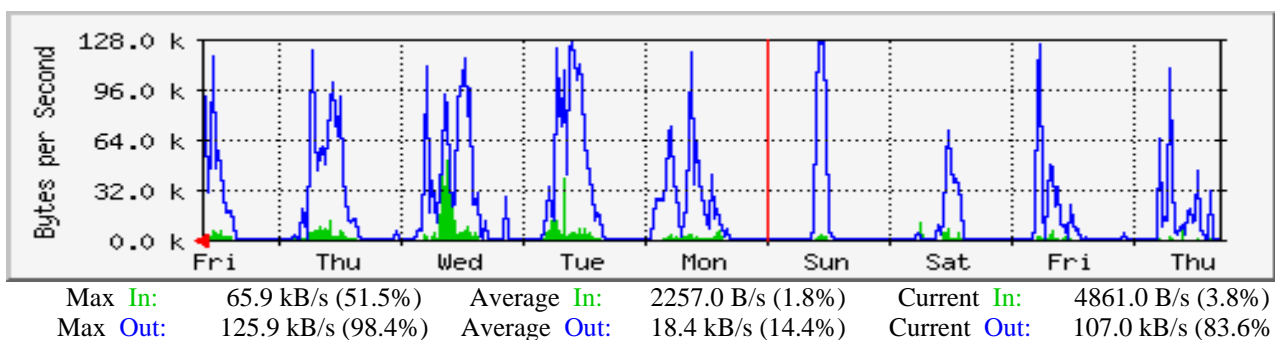| Max In: | 65.9 kB/s (51.5%) | Average In: | 2257.0 B/s (1.8%) | Current In: | 4861.0 B/s (3.8%) |
| Max Out: | 125.9 kB/s (98.4%) | Average Out: | 18.4 kB/s (14.4%) | Current Out: | 107.0 kB/s (83.6% |

Fig. 1.9: 'Weekly graph' statistics of the connection between ENSI and CCK Kasba. The statistics were last updated Friday, 7 April 2006 at 15:25.

1.2. QoS analysis

1.2.1 Voip test (Skype)

VOIP test has been successfully realized between SSSUP (Piero Castoldi, Filippo Cugini) and ENSI (Hela Boucetta) on Thursday 6, April 2006.

Fig. 1.10 shows the amount of traffic measured during the Skype (www.skype.com) session.

UDP packets of 100 Bytes (payload: 58 bytes) have been detected. Less than 4 KBps (~30 Kbps), have been measured in each direction for voice traffic. Extra traffic of about 1.5 KBps (~12 kbps) has been evaluated for the contemporary file transfer (from SSSUP to ENSI). Voice quality was not affected by the contemporary file transfer.

The same type of test has been conducted between two PCs located in the same LAN. Bandwidth utilization for voice traffic is typically higher (~40 Kbps). Also considering file transfer the overall utilized bandwidth does not typically exceed 100 Kbps.
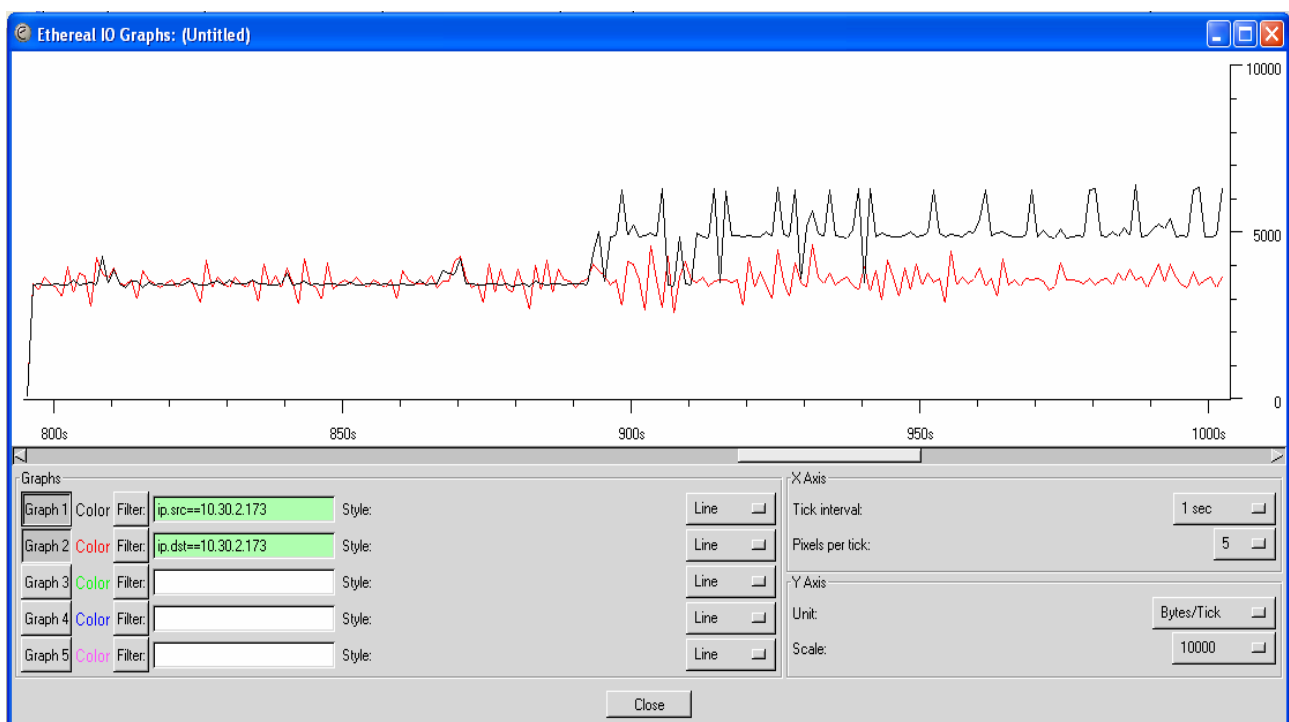

Fig.1.10: Ethereal capture. Black line shows VOIP (Skype) traffic from SSSUP(Ircphonet) to ENSI, red line shows the traffic flow in the opposite direction (in Bytes/s). The left side (t<890s) shows only voice traffic. The right side (t>890s) shows voice and file data transfer from SSSUP to ENSI.

1.2.2 Bandwidth Estimation

The available bandwidth between SSSUP and ENSI has been estimated using the bing tool.
Bing is a point-to-point bandwidth measurement tool (hence the 'b'), based on ping.
(http://spengler.econ.duke.edu/~ferizs/bing.txt)
Results (Fig. 1.11 and 1.12) show an average available bandwidth higher than 500 kbps.

Link	Min BW [Mbps]	Max BW [Mbps]	Avg BW [Mbps]
SSSUP Irephonet-SSSUP Central Office	0,5	55	2
SSSUP Central-POP Garr Pisa	0,5	86	2
POP Garr Pisa-POP Garr Torino	0,5	150	2
POP Garr Torino- POP Garr Milano2	0,5	20	2
POP garr Milano2-POP Garr Milano1	0,5	30	2
POP Garr Milano1- POP Geant Milano1	0,5	30	2
POP geant Milano1-POPEumedconnect Catania	0,5	10	2
POPEumedconnect Catania-POP ATI Tunisia	-	-	-
POP ATI Tunisia-POP CCK kasbah	0,5	10	2
POP CCK Kasbah-ENSI	-	-	-

Fig. 1.11: Bandwidth measurements between SSSUP and ENSI using Bing tool.

Link	Min BW [Mbps]	Max BW [Mbps]	Avg BW [Mbps]
SSSUP Irephonet-SSSUP Central Office	20	40	30
SSSUP Central-POP Garr Pisa	10	15	12
POP Garr Pisa-POP Garr Torino	10	12	11
POP Garr Torino- POP Garr Milano2	10	11	10,5
POP garr Milano2-POP Garr Milano1	8	12	11
POP Garr Milano1- POP Geant Milano1	8	10,5	12
POP geant Milano1-POPEumedconnect Catania	8	10	12
POPEumedconnect Catania-POP ATI Tunisia	-	-	-
POP ATI Tunisia-POP CCK kasbah	20	40	30
POP CCK Kasbah-ENSI	10	15	12

Fig. 1.12: Bandwidth measurements between SSSUP and ENSI using Bing tool (packet size 10 kb).

1.2.3 Delay Estimation

The delay estimation has been obtained exploiting both the Bing tool and the Traceroute tool. Results (Fig. 1.13) show delays included in the range between 75 and 300 ms.

Link	Delay (Bing) [ms]	Min Delay (Traceroute) [ms]	Max Delay (Traceroute) [ms]
SSSUP Irephonet-SSSUP Central Office	2	2	35
SSSUP Central-POP Garr Pisa	5	30	300
POP Garr Pisa-POP Garr Torino	10	20	150
POP Garr Torino- POP Garr Milano2	12	90	300
POP garr Milano2-POP Garr Milano1	12	70	250
POP Garr Milano1- POP Geant Milano1	13	50	250
POP geant Milano1-POPEumedconnect Catania	40	50	250
POPEumedconnect Catania-POP ATI Tunisia	-	80	300
POP ATI Tunisia-POP CCK kasbah	75	100	300
POP CCK Kasbah-ENSI	-	-	-

Fig. 1.13: Delay measurements between SSSUP and ENSI using Traceroute and Bing tool.

1.2.4 Multicast test (Mbone tools)

The multicast-based MBONE tool RAT (Robust Audio Tool, http://www-mice.cs.ucl.ac.uk/multimedia/software/) has been utilized to check if multicast traffic can flow between SSSUP and ENSI. The test failed: multicast traffic is blocked in intermediate routers.

2. Network connection SSSUP-ESSTT

2.1 Route analysis

Traceroute from ESSTT to Ircphonet/SSSUP

```
1  193.95.34.225 to 193.95.34.232  0.808 ms  1.005 ms  0.929 ms
2  192.168.102.69 to 193.95.34.232  338.285 ms  169.534 ms  96.467 ms
3  193.95.52.97 to 193.95.34.232  74.689 ms  76.381 ms  17.231 ms
4  10.1.11.10 to 193.95.34.232  17.776 ms  30.565 ms  192.408 ms
5  193.95.18.75 to 193.95.34.232  194.244 ms  203.054 ms  173.716 ms
6  no reply
```

Traceroute from Ircphonet/SSSUP to ESSTT

```
 1    <1 ms    <1 ms    <1 ms  10.30.127.5
 2     1 ms    <1 ms     1 ms  10.30.127.1
 3     1 ms     1 ms     1 ms  ru-sssup-rt-pi1.pi1.garr.net [193.206.136.45]
 4     5 ms     5 ms     5 ms  rt-pi1-rt-rm2.rm2.garr.net [193.206.141.33]
 5    30 ms    30 ms    30 ms  so-4-1.car1.Paris1.Level3.net [212.73.207.29]
 6   145 ms    30 ms    30 ms  ae-0-55.mp1.Paris1.Level3.net [4.68.109.129]
 7    37 ms    39 ms    39 ms  as-0-0.bbr1.London1.Level3.net [4.68.128.109]
 8    37 ms    37 ms    37 ms  ae-0-53.gar1.London1.Level3.net [4.68.116.75]
 9    42 ms    37 ms    37 ms  195.50.90.86
10   127 ms   130 ms   131 ms  62.216.146.102
11     *      128 ms   139 ms  193.95.1.10
12   119 ms   132 ms   129 ms  193.95.1.38
13   150 ms   149 ms   155 ms  193.95.66.198
14   163 ms   156 ms   161 ms  193.95.66.194
15   169 ms   165 ms   171 ms  193.95.66.134
16   131 ms     *      142 ms  196.203.130.1
17   151 ms   149 ms   148 ms  196.203.78.20
18     *        *        *     Richiesta scaduta.
19     *      174 ms   181 ms  gtrs.esstt.rnu.tn [193.95.34.232]
```

Traceroute analysis shows that different routes are utilized from SSSUP to ESSTT and from ESSTT to SSSUP.
The reply to traceroute queries is not always returned, thus the identification and the analysis of the strict route is not permitted. Moreover, the route analysis from SSSUP to ESSTT performed in September 2006 and November 2006 determined different results (i.e., different routes)
Compared to the SSSUP-ENSI route, the two routes between SSSUP and ESSTT do not exploit academic and research backbone networks (e.g., GARR and EUMEDCONNECT). Indeed traffic packets flow through the backbone internet networks.

2.2 QoS analysis
2.2 Bandwidth Estimation

The available bandwidth between SSSUP and ENSI has been estimated using the bing tool.
Bing is a point-to-point bandwidth measurement tool (hence the 'b'), based on ping.

Results (Fig. 2.2) refers to the test performed in September 2006. In November 2006 a different route has been identified (shown in section 2.1). The analysis of both routes highlights the network bottleneck in the link between Ati and ESSTT.

Link	Min BW [kbps]	Max BW [Mbps]	Avg BW [Mbps]
SSSUP Irephonet-SSSUP Central Office	500	55	2
SSSUP Central-POP Garr Pisa	500	86	2
POP Garr Pisa-POP Garr Torino	500	150	2
POP Garr Torino- POP Garr Milano2	500	20	2
Internet	-	-	-
Tunisie Telecom	500	30	2
Ati	500	10	2
ESSTT	10	0,6	0,3

Fig. 2.2: Bandwidth measurements between SSSUP and ESSTT using Bing tool. Same results also for packet size equal to 10 kbit.

2.3 Delay Estimation

The delay estimation has been obtained exploiting both the Bing tool and the Traceroute tool. Results show delays included in the range between 100 and 140 ms.

Link	Delay (Bing) [ms]	Min Delay (Traceroute) [ms]	Max Delay (Traceroute) [ms]
SSSUP Irephonet-SSSUP Central Office	2	2	35
SSSUP Central-POP Garr Pisa	6	30	300
POP Garr Pisa-POP Garr Torino	6	20	150
POP Garr Torino- POP Garr Milano2	6	90	300
Internet			
Tunisie Telecom	100	75	80
Ati	110	80	170
ESSTT	140	100	110

Fig. 2.3: Delay measurements between SSSUP and ESSTT using Traceroute and Bing tools.

2.4 Multicast test (Mbone tools)

The multicast-based MBONE tool RAT (Robust Audio Tool, http://www-mice.cs.ucl.ac.uk/multimedia/software/) has been utilized to check if multicast traffic can flow between SSSUP and ESSTT.
The test failed: multicast traffic is blocked in intermediate routers.

3.   Network connection ENSI-ESSTT

3.1 Route analysis

Traceroute from ESSTT to ENSI

```
1  193.95.34.225 (193.95.34.225)  1.014 ms  0.993 ms  0.902 ms
2  192.168.102.69 (192.168.102.69)  5.650 ms  5.673 ms  5.489 ms
3  196.203.78.22 (196.203.78.22)  6.392 ms  14.749 ms  6.335 ms
4  * 11.0.0.2 (11.0.0.2)  229.949 ms *
```

Traceroute between ENSI and ESSTT
```
1  196.203.126.225 (196.203.126.225)  1.142 ms  3.493 ms  1.608 ms
2  11.0.0.1 (11.0.0.1)  221.618 ms  220.040 ms  216.085 ms
3  * 196.203.78.20 (196.203.78.20)  211.885 ms *
4  192.168.102.70 (192.168.102.70)  285.617 ms  239.309 ms  243.250 ms
5  * gtrs.esstt.rnu.tn (193.95.34.232)  551.292 ms *
```

Traceroute analysis shows that the packets between the two considered Tunisian institutions flow follows through the backbone internet networks. In general this route offers good throughput, but sometimes packets experience a very high delay. Moreover, sometimes packet loss is experienced. Results confirm that the bandwidth bottleneck is located in the access networks.