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Proof of Concept Testbed

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Abstract:

This deliverable provides an overview of the proof of concept testing carried out to verify the functionality of Premium IP. It outlines tests of basic functionality required from routers and outlines tests carried out in the wide area and connecting real users with requirements for QoS guarantees.

Keywords: QoS, IP Premium, H.323 users

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1 EXECUTIVE SUMMARY

The revised work plan for SEQUIN recognised the need to have an initial implementation of the testing methodology by implementing a "Proof of Concept" testbed as a pre-cursor to a full set of field trials involving user groups. The goal of the Proof of Concept is to have access to a controlled environment composed of a variety of hardware and underlying technology to verify the functionality of each component required to implement Premium IP. The set of tests performed include laboratory tests for basic router functionality, wide area tests to perform network calibration and tests involving users to verify the QoS provisioning processes.

A set of tests was conducted in laboratories made available by Cisco and Juniper in order to test the router functionality required. These tests have shown that the basic functionality is available on both platforms. Detailed results cannot be presented in this deliverable because they are subject to an NDA with both Cisco and Juniper, but the results show that the functions are performed well. On Cisco 12400 series routers, it is necessary to carefully select the appropriate HW configuration and, in some cases, it has been possible to test the functionalities only on experimental pre-production HW and SW. Full production HW and SW was used for Juniper.

The tests were carried out with the use of smartbits traffic generators and analysers.

A series of tests in the wide area has been planned and conducted. These tests aim at performing network calibration, in other words to understand the performance users can expect. The tests also aim at understanding the interaction between different network technologies, such as Packet over Sonet (POS) and ATM. These have been conducted in Poland, as well as between Poland and Switzerland, and have given clear indications on the baseline performance offered by a network composed of Cisco 7200 series routers, with and without QoS mechanisms in place.

It has not been possible so far to conduct network calibration tests on the French (PLAGE) and Italian (GARR-G) testbed with Cisco 12000 and Juniper routers, due to the general unavailability of the testbeds. Network calibration testing on these two networks will be performed as soon as the testbeds are available and will make use of the smartbits traffic generators and analysers.

A test involving an international user group with requirements for QoS guarantees has been planned. This user group is composed of users from France, Germany, Italy and Switzerland and has a requirement to use H.323 video-conferencing. The goal of this test is to ensure the correct functionality of the Premium IP model in a multi-domain and multi-technology environment. It also aims at verifying the service provisioning processes. The test was planned to take place in November 2001 using GÉANT as the transport network rather than TEN-155. Due to the delayed connection of France and Italy to GÉANT this has not been possible, so the test is taking place in December 2001. No results are available yet.

The deliverable outlines how performance monitoring will be done and outlines plans to carry out tests with another international user group, from the IST project MOICANE.

In conclusion, although only a part of the planned tests have been performed, the results have proved encouraging and the interest of at least one other international user group at this early stage is indicative of the applicability of Premium IP to satisfy user's needs.

2 INTRODUCTION

This deliverable outlines the activities that have been carried out and that are planned for the proof of concept testing of the Premium IP implementation model. The proof of concept testing aims at achieving a number of goals. First of all, it is necessary to run a series of tests that will verify the functionality required on the routers. D3.1 outlined which functionalities were required (classification, policing, queuing, congestion avoidance) and which support was offered by a number of router vendors and types. These tests aim also at providing an indication of the impact on the performance of the four QoS parameters identified in D2.1 (capacity, packet loss, delay and ipdv) which was accomplished using SMARTBITS traffic generators from SPIRENT. Secondly, it aims at testing the operational model whereby a number of different router types (Cisco, Juniper) are used in combination to deliver an end-to-end service using different underlying technologies (SDH, ATM, Gigabit

Ethernet). Finally, the tests need to run in an operational interdomain environment to verify also the operational processes required for the provisioning of Premium IP.

The testing focuses mostly on Premium IP, although basic router functionality tests have also addressed IP+. The reason for limiting the bulk of the tests to Premium IP functionality is simply that the definition of QoS work package has focused mainly on Premium IP. IP+ has been considered a potentially interesting service which is, however, too difficult to specify with the same degree of completeness as Premium IP.

The following sections outline tests that have been performed in laboratories (to test the basic router functionality and their impact on QoS performance metrics) and on national testbeds (for calibration and multi-technology tests). Two further sections outline plans for testing operation in a multi-domain environment. One set of tests, involving H.323 users, was planned for November 2001 but was not possible to perform because of the late delivery of NREN connections to GÉANT. This test case is target to be performed in December 2001. A further test case in an operational multi-domain environment is planned for Q1/02 whereby the IST project MOICANE will make use of the Premium IP functionality. Testing with MOICANE will effectively be performed in the context of WP6, but an outline of the test is provided here given that initial discussions with the project participants have taken place.

The proof of concept testing aims therefore at proving that the basic functionality required on routers is available and performs to expectations and at proving that the Premium IP model is scalable and manageable in a multi-domain and multi-technology environment.

The next section summarises which are the QoS performance metrics of interest. SMARTBITS have been used in laboratory and national testbed environments to measure these parameters, whilst a proposed monitoring infrastructure for the operation of Premium IP in production networks is outlined in section 9.

3 QOS PERFORMANCE METRICS

The Premium IP implementation model aims at ensuring that the four base performance parameters, as defined in [1], are kept within their profiles, which are described in relevant SLA/SLS documents.

The desired service quality may be achieved only if all of them are within their limits (unless some of them are not included in a given SLS). A summary description of the four parameters follows:

- One way IP packet loss.

  This parameter shows the percentage of the packets that have been sent, but did not reach the destination. The increase of this parameter indicates the network congestion. One way IP packet loss can be calculated from the equation:

$$IP\_Packet\_Loss = \frac{IP\_Packets\_Sent - IP\_Packet\_\mathrm{Re}ceived}{IP\_Packets\_Sent} * 100\%$$

- One way IP packet delay (or Round Trip Time).

  This parameter shows the IP packet travel time from the source to the destination. Measurement of one-way packet delay requires fine time synchronization on both ends of the packet route. This may be achieved either by use of GPS receiver or with the use of NTP protocol. In addition the sending device should timestamp the outgoing packets, so the travel time may be checked. Similarly to the one-way packet loss, increase of this parameter is a good indicator of the network congestion. There is also a good approximation of the one-way packet delay parameter, called IP packet Round Trip Time (RTT). This parameter represents the total time necessary for packet travel from the source to the destination and back to the source. In contrary to the one-way packet delay, the RTT does not require any synchronization and can be easily measured with such tools as ICMP ping.

- IP packet delay variation – IPDV (also referred to as *jitter*).

  This parameter is measured for a pair of packets and can be most simply expressed as the difference between one-way delay of first packet and one-way delay of the second packet. The value of this parameter should be the lowest possible.

- The bandwidth available for the stream.

  The bandwidth available for the stream should be understood as the maximum IP-level throughput between users' endpoints.

Another approach to QoS performance monitoring allows for observing perceived SLS metrics, such as H.323 transmission quality. Previous measurement tests [2] indicate that some of the applications (especially these using connection oriented protocols, such as TCP) may get affected by the under-provisioned network state. In test scenarios involving users, both QoS performance monitoring approaches will be used.

4 LABORATORY TESTS OF THE ROUTER FUNCTIONALITY TO SUPPORT PREMIUM IP AND IP+

Using laboratory facilities made available by Cisco and Juniper, it has been possible to test the functionality required on routers to implement Premium IP and IP+. The tests have focused on the gigabit routers from Cisco and Juniper. One requirement of the tests was to test these features at STM-16 and STM-64 capacities.

The results presented in this section are only a summary of the results obtained, as all further details of the Cisco and Juniper router functionality tests are under a Non Disclosure Agreement (NDA) and cannot be presented here.

The features that are needed for implementing Premium IP and IP+ that were tested are: rate limiting, marking, queuing and congestion avoidance mechanisms. They have been tested on Cisco 12416 routers equipped with Engine3 or Engine4 line cards and Juniper M40 and Juniper M160 routers.

4.1 Rate limiting and marking

The rate limiting and the packet marking are part of the traffic conditioning functionality. These mechanisms ensure that the traffic entering a Diffserv domain conforms to the rules specified by the Service Level Agreement.

During the test a distribution of four different packet sizes, which were created with the use of a traffic generator such as SMARTBITS, has been injected into a router. Table 1 summarises the packet size distribution used. The aim of this test was to evaluate if the rate-limiting function is performed properly, according to the configured value and to check its behaviour in terms of fairness of resource allocation in respect of the packet size distribution. During the test, the router CPU load was observed.

Packet size	Flow BW proportion
40 bytes	56%
52 bytes	4%
576 bytes	17%
1500 bytes	23%

Tab. 1. Bandwidth distribution per packet size.

Two sets of tests were performed. In the first instance, the rate limitation was based on the Class of Service field value. Excess, or non conforming, traffic was dropped. The values of the rate limitation was gradually increased in order to evaluate the impact on the router performance. In the second instance excess, or non conforming, packets were remarked to the CoS corresponding to Best Effort IP (0)

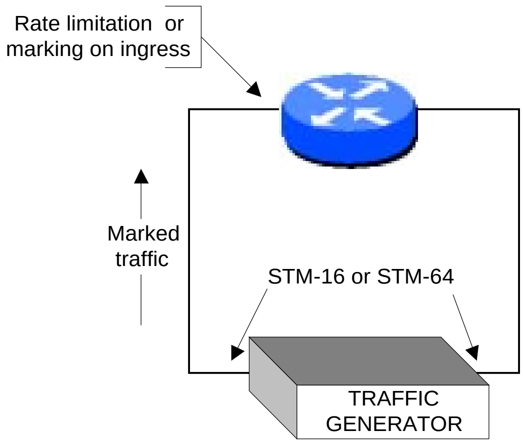

Fig. 1. Topology of the first rate limitation test.

The summary results for Cisco and Juniper are:

- Cisco

  On Cisco routers equipped with experimental versions of Engine3 quad-STM-4 cards the rate-limitation is performed with the use of the CAR functionality. It was necessary to use these experimental versions rather than production versions because, at the time of testing, it was clear that these cards would be required for provisioning backbones running Premium IP, but the cards were not yet ready for full production. The Engine3 cards can perform CAR in hardware at STM-16 line-rate. The tests showed that the rate limitation per class of service worked properly and the CPU load was kept low. The non-conforming packets were fairly discarded in respect of the packet size distribution.

- Juniper

  On Juniper routers the rate-limiting and packet marking functions are performed by the central Internet Processor II (IP II) ASIC. The rate-limiting was tested on STM-16 interfaces on M40 and M160 platforms and on STM-64 interfaces on M160 routers. The IP II is able to rate-limit as well as mark the packets whilst the load of the IP II was a function of the number of packets discarded. However the packets were not fairly discarded with respect to the packet size distribution.

The conclusion of these tests is that the traffic conditioning functionalities work well, with artificial traffic, on both Cisco and Juniper routers. It is important, however, to use the correct interface card type on Cisco routers.

4.2 Scheduling mechanisms

Scheduling mechanisms are used to provide guaranteed capacity to the different classes of traffic. In most cases Weighted Round Robin or Leaky Bucket algorithms are used to serve different queues containing different classes of traffic.

The fairness of single scheduling mechanism servicing several queues was tested. The main goal of these tests was to evaluate whether the scheduling mechanism allocates the bandwidth in accordance to the weight allocated to a queue. In the first test several flows with the same characteristics, but tagged with different values, have been injected into a router. The router forwarded all the flows through the same transmit interface and mapped each flow into a different queue.

The second test focused on the delay measurements and had the following stages:

1. A single flow (called “A”) was sent into a queue and the one-way delay was monitored. During the test the router output interface was not subject to congestion;
2. Background traffic was added to the flow, but without subjecting the output interface to congestion.. The traffic was sent to the same queue as flow "A";
3. Background traffic was increased in order to congest the output link. The background traffic was mapped into the same queue as the “A” flow;

4. The background traffic was mapped into another queue than the "A" flow. The output link was not congested;
5. The background traffic was increased in order to congest the output interface.

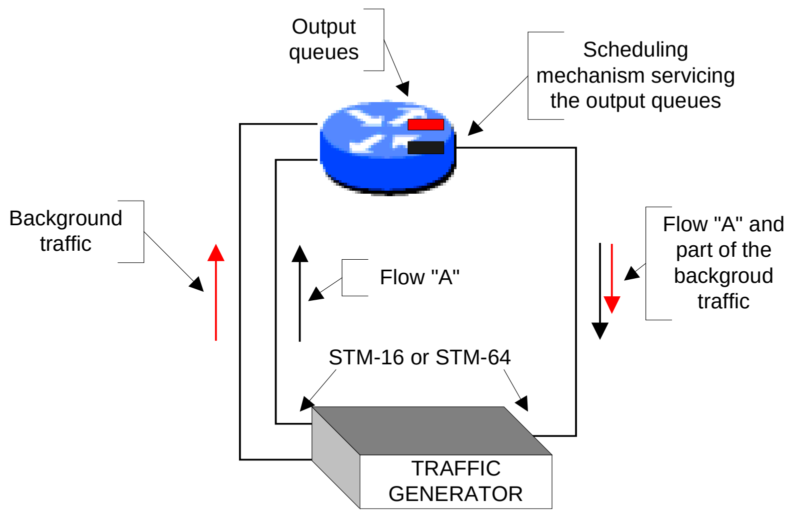

Fig. 2. Test of Scheduling mechanisms.

The summary results for Cisco and Juniper are:

- Cisco

The tests were done with the use of STM-16 Engine4 interfaces. The scheduling mechanism is the Modified Deficit Round Robin (MDRR). Eight queues can be configured, of which one can be configured as a Low Latency Queue (LLQ) and used in 2 modalities (strict-priority mode or alternate-mode).

The tests showed that the bandwidth was distributed fairly, in respect of the weight allocated to each queue. In cases where the output interface was subject to congestion, the LLQ in strict-priority mode gave the best results in terms of one-way delay. During this test, the flow "A" was mapped into the LLQ and the background traffic into another one.

- Juniper

A juniper M-160 with STM-16 interfaces was used. The scheduling mechanism is based on the Weighted Round Robin (WRR) algorithm. Four queues can be configured.

The tests showed that the bandwidth was fairly distributed among the queues according to their allocated weight. During the fifth stage the delay of the traffic mapped into the priority queue was lower than the delay of the other traffic.

The conclusion of this set of tests is that the scheduling mechanisms work well on both Cisco and Juniper routers, with artificial traffic.

4.3 Congestion avoidance mechanism

Congestion avoidance techniques monitor network traffic load in order to anticipate and avoid congestion in the network bottlenecks. An example for such a mechanism is RED (Random Early Detect).
These techniques are often enhanced with differentiated drop-preference mechanisms that allow more aggressive congestion signalling (dropping) to some classes of traffic in order to protect other classes. Examples of these mechanisms are Weighted RED (WRED) and RIO (RED with In/Out).

One of the concepts of IP+ is that it could offer a minimum bandwidth guarantee, independently of the traffic load of an interface. If spare capacity is available, more bandwidth can be provided to the users. A typical example could be that of sharing capacity on a heavily utilised circuit. Several users may wish to have a committed share of the capacity of a circuit, whilst each user may wish to utilise any bandwidth left unutilised by another user. For example, on an STM-1 circuit there may be 3 users each wishing to have a guarantee of 50Mbps. But, if one of the users does not utilise its allocation of 50 Mbps this can be used by the other users. It is possible to establish that the first 50 Mbps of each user is tagged with a particular value, and this traffic will never be dropped no matter what the utilisation level of the circuit. This is conventionally called green traffic. Any traffic in excess of 50Mbps will be tagged with a different value, conventionally called red, which means that this traffic will be dropped whenever a defined situation of congestion occurs. This defined situation may be the queue length of an output interface. Some router vendors offer the possibility to implement an intermediate stage whereby the packets are tagged yellow, which means that the drop probability of these packets is less than the red packets but more than the green packets.

During the test one flow tagged with the three different colours (or three different precedence values, one corresponding to green, one to yellow and one to red) was sent. All the packets were sent into the same queue of a congested interface. A different drop profile was associated to these colours (an aggressive drop profile for the red packets and a less aggressive one for the green ones). The aim was to protect the green packets and to have the red packets dropped before any yellow ones and the yellow packets before any green ones. The topology of the test is depicted on 3.

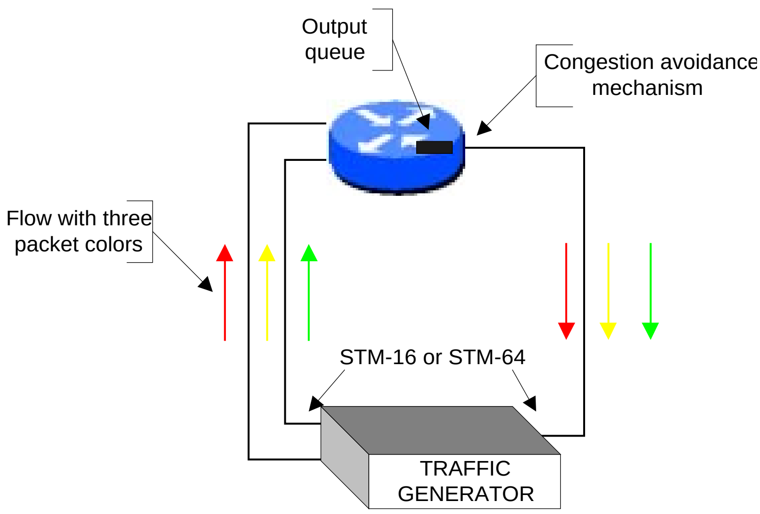

Fig. 3. Topology of the first congestion avoidance test.

In the second test several flows have been sent, each of them marked with different colour. The goal was to check the dropping fairness between the different flows. These tests were performed with the use of UDP traffic, as there were no TCP traffic generators available.

- Cisco

The tests were done on STM-64 Engine4 line cards with Weighted Random Early Detection algorithm. Drop profiles based on the packet precedence values were configured in the following way: the green packets were fully protected, the red packets were dropped before any yellow ones and any yellow packets before any green ones. The bandwidth was fairly distributed among several flows (fair discard between the flows).

- Juniper

The tests were done on M160 router with STM-16 cards. Two drop profiles can be defined for each queue according to the value of the PLP bit. The green packets were protected up to a "green bandwidth" of 90% of the total line bandwidth. With the tested drop profiles, the bandwidth was randomly distributed among the different red flows.

The conclusion of these tests is that the functionality woks well on both Cisco and Juniper. Cisco can reserve 100% of the link bandwidth to green traffic, whilst Juniper is limited to 90%

5 NETWORK CALIBRATION TESTS

The measurement infrastructure is an essential part of validating the QoS definition and implementation. Spirent has made four Smartbits traffic generators and analysers available on an open-ended loan arrangement for the SEQUIN project. Two of these devices have been hosted at PSNC and the other pair at GARR-G.

SmartBits 600 (SMB-600) is a portable and compact, high-port-density system for network performance testing. It holds up to two modules that can support up to 16 10/100 Mbps Ethernet ports, 4 SmartMetricsT Gigabit Ethernet ports, 4 Fibre Channel ports, 1 10GbE port, a set of Terametrics POS OC-48, OC-12, OC-3 or a mixture of these port types. The devices held at PSNC were equipped with one Terametrics POS OC-48c/STM-16 SM card, one POS OC-3c/OC-12c/ STM-12 SM card and 10/100 Base T Ethernet (6 Port) card.

SMB-600's can be daisy-chained together to achieve higher port density, enabling users to perform automated large-scale testing in Quality Control and high-volume production environments. Up to 512 chassis can be synchronously connected with SmartBits multi-chassis extension units. The devices can be synchronised either by en external clock source or can be synchronised to another Smartbit, thus building a stack consisting larger number of devices.

The SMB-600 is easily controlled by a PC through a 10/100 Mbps Ethernet connection and uses a Windows-based interface. Spirent provided also a set of applications to be used with the SmartBits to generate, analyse and present data: SmartWindow v7.20, SmartApplications v2.40, SmartLIb Programing Library v3.11, SmartFlow v1.30, SmartVoIPQoS v1.00, ScriptCenter v1.20 and WEBSuite v1.00Beta.

During the measurement phase of the testbed construction, the SMB-600 devices were used to validate the measurements obtained with software tools. The measurement process was performed in two stages on two separate testbeds. One testbed was built over a TEN-155 MBS ATM connection from Poznan to Bern which connected two Cisco 7200 routers and two Linux stations generating/measuring traffic. The second testbed was located at PSNC and consisted of two Cisco 7200 routers connected with direct ATM link and two SMB-600 devices generating/measuring traffic.

Unfortunately, the use of SMB-600 traffic generators/analyzers in an international link was impossible due to lack of GPS devices, which could allow for the accurate time synchronization. SMB-600 does not support NTP as well, so their use has been limited to the local laboratory only.

The main goal of the tests was to verify the QoS provisioning features on 7200 routers. These tests involved transmission of data flows for different traffic protocols and different traffic intensity. Tested protocols included UDP and TCP streams, with the generated stream bandwidth ranging from several percent of the link bandwidth to over 100% of the link bandwidth. Also packet TOS field marking feature has been used, in order to ease the router filters configuration. All the tests have been performed with the use of SmartFlow application.

The tests confirmed high usability of the SMB-600 boxes and helped to assess the software measurement tools accuracy and feasibility. During tests some suggestions regarding the measurement software and techniques have been gathered and passed onto Spirent for feedback..

It is also planned to carry out, using smartBits, a series of network calibration tests. These tests are planned to be performed on Plage and GARR-G and their aim is to understand the basic performance values users can expect from a network. The calibration tests will outline delay and ipdv performance metrics in an empty network condition with no QoS features enabled and with QoS features enabled. The tests will then increase load on the network, with artificial traffic and the same measurements will be made. Due to ongoing problems on Plage and

GARR_G, these tests have not yet been performed but they have been partly carried out in an international scenario outlined in the following section.

6 INTERNATIONAL TESTS ON CISCO7200 BETWEEN BERNE AND POZNAŃ

The test scenario relied on two ATM networks - in Berne (Switzerland) and PSNC (in Poland), connected via the TEN-155 European Research Network. The main goal of the measurements was provide enough data toward the characterisation of the network behaviour under diverse conditions and the usefulness of selected Diffserv mechanisms in implementing the IP-premium service with the use of Cisco routers.

The usage of three neighbouring ATM networks allowed for a simplification in the framework to be considered. In reality, although there were three distinct ATM domains (Poznan, TEN-155 and Switch ATM networks) they were evaluated as just one, depicted by 4. In this case, the IP mapping into ATM and the related QoS settings were concentrated on the border routers (Cisco router 7200 and 7200VXR with ATM and Fast Ethernet interfaces).

The idea for the measurements was to configure the Cisco routers with DiffServ capabilities so that the core network behaved as a DiffServ network model. In addition, it has been considered that the access networks (Fast Ethernet) were over provisioned and so only the constraints of the core network were estimated.

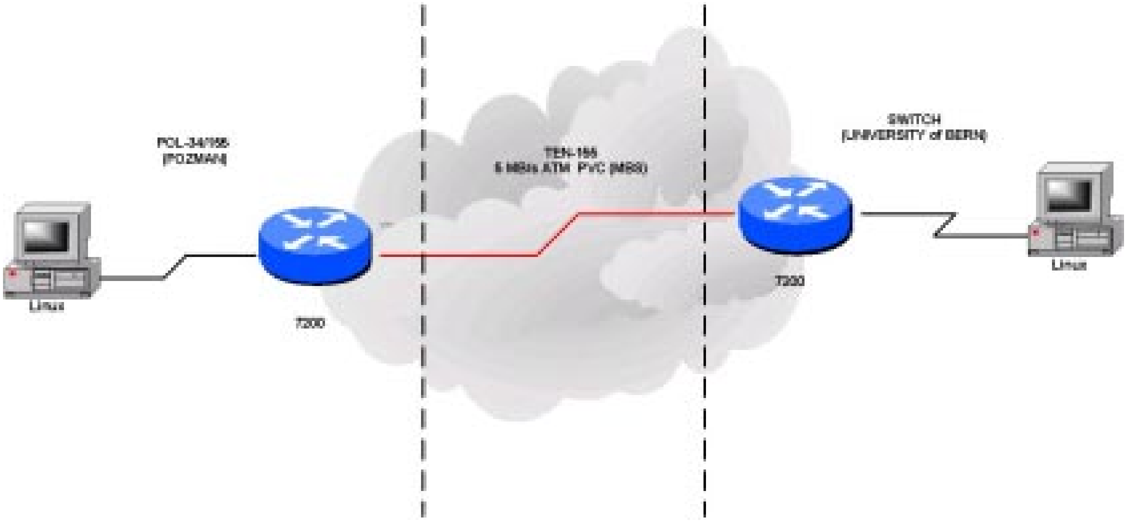

Fig. 4. Poznań-Berne test network topology.

The network, (or being more precise – the allocated PVC), was considered to act under two distinct conditions: network over-provisioned (having less load that the estimated capacity) and under-provisioned (the traffic delivered to the network border router exceeds the maximum network capacity). The situations evaluated were as follows:

1. Testbed calibration in an empty network condition. The purpose of this phase has been to understand the behaviour of the standard traffic parameters under these circumstances as well as tools accuracy.
2. Network performance for different levels of load, under and over provisioned cases, and for varying packet sizes. The purpose of this test was to evaluate the overall Diffserv performance in providing QoS guarantees.

Cisco Class Based Weighted Fair Queuing has been used to provide service differentiation, priority traffic had reserved bandwidth guarantee, while other traffic was served as "best effort" with fair queuing techniques.

In order to achieve accurate results, all of the metrics were measured on an end-to-end basis, namely between two Linux machines. Furthermore some of them were considered one-way, while others for round trip cases (2,3). This was caused by the limitation of tools and different time requirements (for sufficient evaluation) of each of the measured parameters.

With regards to the parameters evaluated, the following metrics were adopted:

1. Goodput: measured in Kbps and considering only the effective data, excluding the network IP, TPC/UDP and ATM overheads. Computed as average for the whole measurement time (these one-way measurements

were performed with the use of Netperf TCP-STREAM test). Tests were performed for 10 packet sizes with the duration of 200 seconds for each packet size, resulting in a total of 2000 seconds measurement time.

2. Loss: measured in percentage referring to the difference between the amount of packets transmitted and received during the evaluation time (measured with the use of round-trip ICMP PING); a rate of one packed per second was used with 600 packets of each size, which amounted for 6000 seconds of measurement time
3. Delay: measured in ms and only for round-trip (full-duplex mode) cases. In all cases a rate of one packed per second was used with 600 packets of each size, which amounted for 6000 seconds of measurement time (round-trip ICMP PING used for measurements);
4. IPDV: measured in ms and referring to the deviation of average delay. (measured one-way with the use of RUDE/CRUDE set). 200 packets of each frame size, with the speed of 1 packet/s were analyzed, totaling for 2000 seconds of measurement time.

The tests allowed for observation of some common properties of flows in congested link condition with Diffserv enabled devices.

One way IP packet delay (or Round Trip Time) – As long as the network is in over-provisioned state, the value of this parameter is constant and depends on the packet length only. One way delay increases rapidly when the link becomes overloaded (under provisioned). This parameter value may be reduced when CBWFQ is used for premium traffic. Increased delay is caused mostly by the router queues. Further reduction may be achieved by using congestion avoidance mechanisms (RED, ECN). The use of RED/ECN mechanisms is considered recommended for under-provisioned links.

IP packet delay variance – IPDV. Measured IPDV value with network load was 10 to 20 times higher that a jitter value for empty network. Nevertheless, when CBWFQ was used it was kept at the highest level of 2 ms, which justifies the use of CBWFQ for video transmission quality of service provisioning.

The bandwidth available for the stream. Generally there were no problems with bandwidth provisioning. There is one issue however – a higher level protocol bandwidth may be guaranteed only in over-provisioned network state. When the network is congested, only the bandwidth on the IP-protocol level can be guaranteed. This is caused by packet dropping at the congested interface. Dropped packets have to be retransmitted, what consumes additional bandwidth.

Packet loss – anticipated packet loss for traffic not exceeding guaranteed bandwidth should be equal to zero. In most cases this requirement has been fulfilled, although due to some ambiguous results some further evaluation is required.

More detailed information about the test results can be found in [4].

7 INTERDOMAIN H.323 USERS TEST SCENARIO

The proper overview of the QoS provisioning mechanisms is not possible without testing on production networks. Therefore, besides the tests in lab and using the artificial traffic, the international test case involving production networks is planned .

The test scenario will include a multi-domain environment composed of 4 high and lower speed national networks connected via the GÉANT backbone. There are users from Germany, France, Switzerland and Italy. Such a composition will help to investigate the issues concerning the interaction of those two types of networks (high/low speed) and understand under which conditions it is necessary to deploy QoS on the higher speed networks.

The test case presented will also include different transmission technologies such as ATM, POS, Ethernet, GigabitEthernet allowing the project participants to validate the QoS techniques with use of different technologies providing connectivity to the users.

The testbed will be composed of a variety of networking equipment coming from different vendors. There are devices from Cisco, Juniper and others, each with its own set of techniques for packet classification, policing and queuing functions. This will enable to test the detailed behaviour of each technique and the interaction between the different technologies on various equipment.

H.323 users have been chosen by Sequin project participants because of the requirements they have, which today are not met by the existing network. The H.323 users are expected to have a real income from the QoS techniques tested within Sequin project.

7.1 H.323 users

The intention was to recruit a group of international users from the European community. They would be expected to have a good knowledge of the Quality of Service requirements. The widespread use of audio/video streaming and conferencing over the Internet (especially in the research and education community) presents many challenges, including increased demand for bandwidth and Quality of Service. This demand will result in development, deployment and operation of communications infrastructure, capable of supporting differentiated Quality of Service based on applications requirements. Such an environment is an excellent opportunity to test (and implement) the IP Premium service defined within the Sequin project.

The tests will involve a group of users from H.323 videoconferencing community, in particular TF-STREAM Task Force in TERENA [5], which volunteered to take part in the test phase. This TERENA Task Force aims at researching and testing in Europe real usage and scalability of audio/video streaming and conferencing.

Two key objectives of the Task Force are:

to determine the suitability of audio/video streaming and conferencing for the research community in Europe,

to co-ordinate diverse real time multimedia initiatives, to assist and validate high-bandwidth pilot projects.

Members of TF-STREAM Task Force are present in most of the countries that have participants in the Sequin project, in particular those where national testbeds and connectivity to the GÉANT network are available. Four countries have been chosen to take part in the real users tests: Switzerland, France, Italy and Germany.

7.2 Test scenario and testbed overview

The implementation of the IP Premium service on an end-to-end scale in the European environment means that traffic crosses multiple domains. In order to carry out tests with H.323 community to validate the architectural model and techniques for implementing IP Premium service, a number of national testbeds together with a core network will be used.

The testbed is composed of 4 high and lower speed national networks connected via the GÉANT backbone. There are users from Germany, France, Switzerland and Italy. The general topology is depicted in Fig. 5.

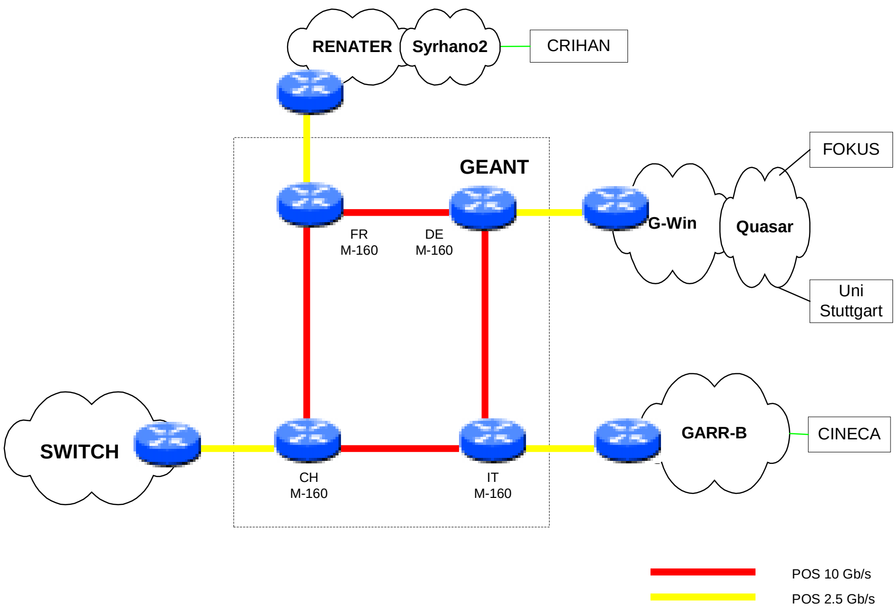

Fig. 5. H.323 testbed overview.

The connectivity between users in the countries mentioned above will be provided by the GÉANT core. There is a core of four routers within GÉANT: one access router in each country where the users of H.323 Task Force exist. The routers are connected with 10 Gb/s POS links and the test networks are connected to the core with 2.5 Gb/s POS links.

Detailed information about each of the connected national parts of the testbed is provided in the following sub-sections.

7.2.1 QUASAR

The Quasar [6] testbed is provided by DFN. It consists of three networks. The local testbed at the campus of the University of Stuttgart is connected using the G-WiN core network to the other local testbed - FOKUS in Berlin. The G-WiN core network interconnects the two sites using STM-1 SDH point-to-point circuits. Such a complex infrastructure enables to test the QoS mechanisms using several QoS provisioning strategies on different network sections. The overview of network topology is depicted in Fig. 6.

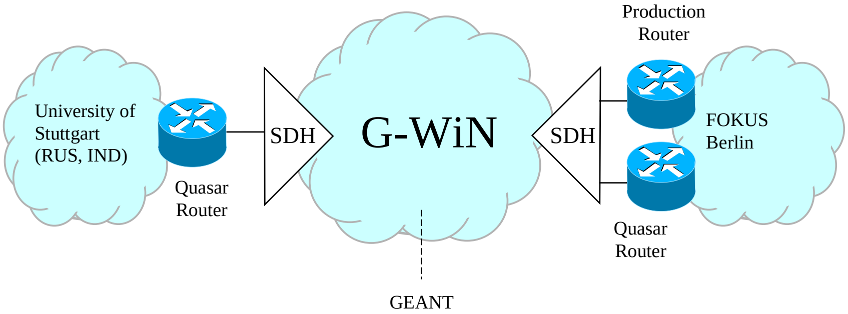

Fig. 6. Topology of the Quasar testbed for H323 tests.

The local testbed in campus of the University of Stuttgart is based on POS and DiffServ over ATM technology. There are two sub-networks in two different places: at the Computing Centre of the University of Stuttgart (RUS) and at the Institute for Communication Networks and Computer Engineering (IND). The sub-networks are connected using ATM as well as POS technology. At the FOKUS side only one sub-network in Berlin is connected to the Quasar testbed. The local testbed at FOKUS is based on FastEthernet and ATM.

The RUS access router not only provides access to the G-WiN-POP but also connects a local sub-network to the backbone, an Ethernet network represented by QT1. At the IND site, the line is also terminated by a CISCO 7200 VXR router equipped with a POS interface. This connection is used by the partners exclusively. Therefore, any intermediate equipment has no influence on the traffic. Parameters on the nodes can be set according to our requirements. While using POS the hosts of the IND sub-network are simply connected to the router by a FastEthernet LAN. Host QT2 represents the sub-network.

The detailed topology of the Quasar network is depicted in Fig. 7.

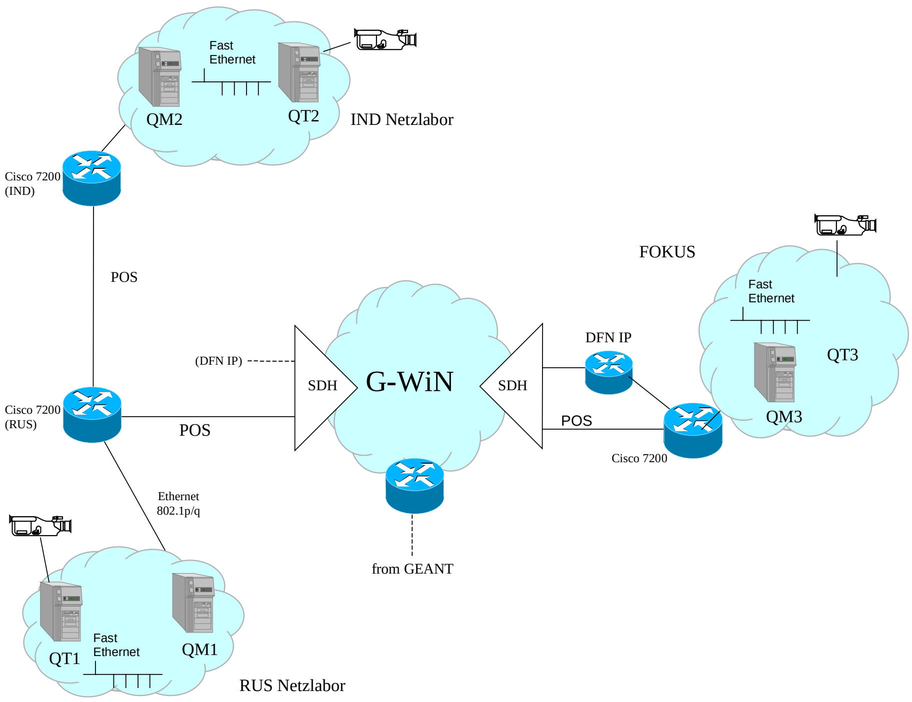

Fig. 7. Quasar network detailed topology for H323 tests.

For the H323 experiment at FOKUS only one sub-network will be connected to the Quasar testbed. The Quasar access in Berlin towards the G-WiN infrastructure will also, as in Stuttgart, use a CISCO 7200VXR, equipped with POS, ATM and Fast Ethernet interfaces. Two sub networks are connected to this router, an ATM network not shown here and a Fast Ethernet network represented by QT3. All networks are used for test and measurement purposes only, therefore an undisturbed test environment can be set up.

In Quasar we represent the sub-networks by end systems called Quasar Terminal (QT) connected to this sub-network. This end system can run standard applications or act as a test system in our network configuration. During the H323 experiments this Quasar Terminals will run the video conferencing software. Additional measurement points in our networks are called Quasar Monitor (QM) and are also assigned to a sub-network. These monitors are connected to an Ethernet Hub or to an optical splitter in case of ATM.

The Quasar testbed is connected via the FOKUS production network with its ISP DFN to GEANT and the rest of the H.323 infrastructure.

7.2.2 GARR-B

The Italian GARR-B network provides connectivity for H.323 users in CINECA [7]. The GARR-B network is made by a core of transport and concentration routers and uses Cisco 12000 router with POS 2.5Gb/s interface to connect to the GÉANT network. There will be ATM2 Mb/s PVC-CBR channel to ensure connectivity between CINECA border router and GARR border router to GÉANT. The network topology is shown on Fig. 8.

At the CINECA side the videoconferencing equipment will be connected to Cisco 6590. On a path between this device and a border router to GARR-B there is a firewall and traffic shaper that can guarantee and enforce capacity limitations per source or application. There is also a possibility to bypass the LAN devices and connect directly to the border-gw router.

H.323 equipment in CINECA is composed of Polyspan 128 Viewstation and MCU Ezenia Encounter NetServer.

In order to precisely measure the one-way delay, RIPE TT systems will be used.

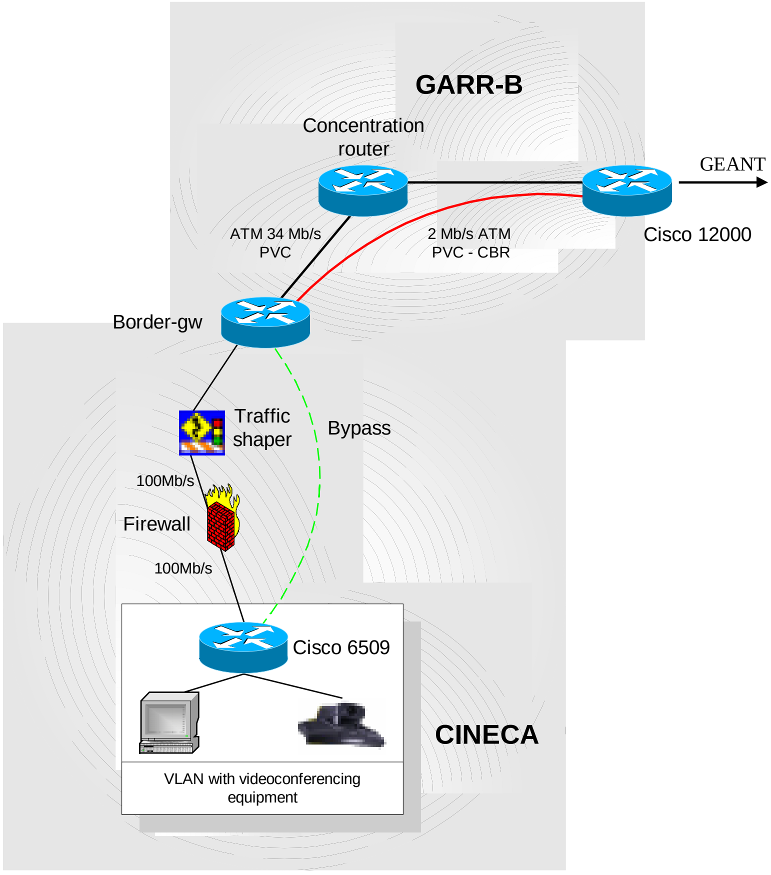

Fig. 8. Italian testbed topology.

7.2.3 SWITCH

The SWITCH network consists of two parts: in CERN [8] in Geneva and in ETHZ (Swiss Federal Institute of Technology) [9] in Zurich. The network's part in CERN provides connectivity to the GÉANT core using 2.5 Gb/s link. CERN hosts SWITCH's Cisco 7600OSR router, which is going to be connected to the same type of router on ETHZ side with Gigabit Ethernet link.

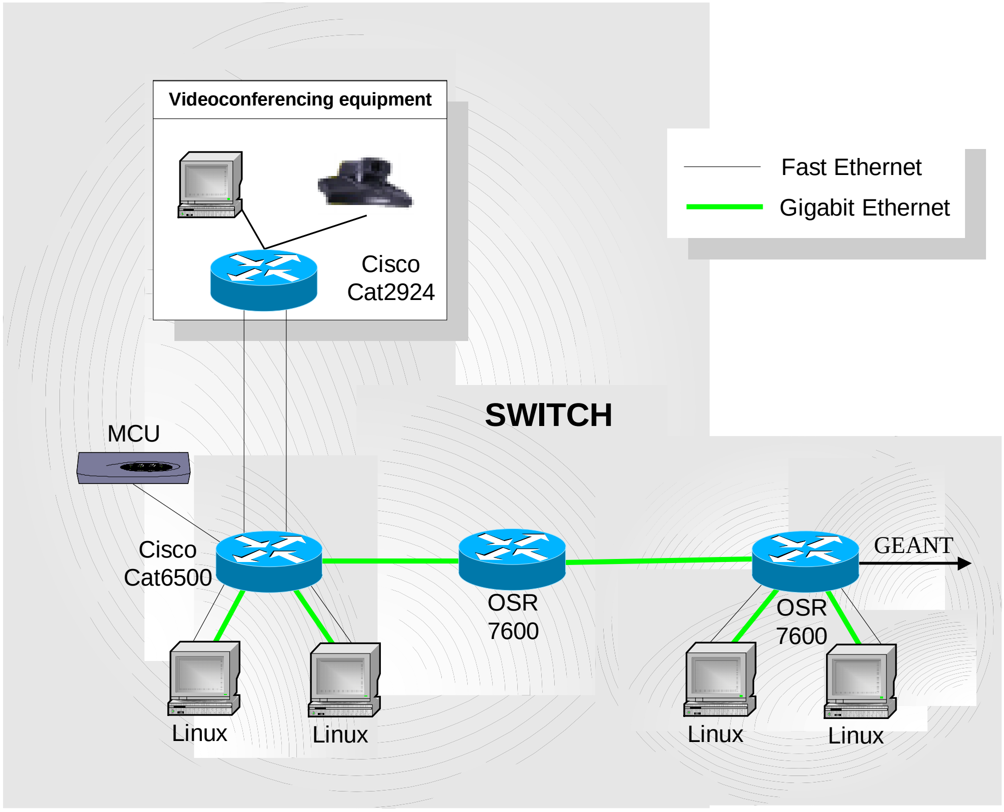

Fig. 9. SWITCH test case topology.

ETHZ sub-network is based on Cisco Catalyst6500 and Catalyst2924 connected by Fast Ethernet links. In terms of H.323 tests, there is dedicated equipment like video camcorder, Accord MGC100 Multipoint Conferencing Unit (MCU), Radvision NGK-200 H.323 gatekeeper [10], Tandberg1000 desktop system and VCON Vigo.

There is also a pair of Linux based workstations connected on both sub-networks in Geneva and Zurich which could be used for monitoring purposes.

7.2.4 RENATER

The test case set-up in France consists of RENATER and SYRHANO2 networks. SYRHANO2 is the regional education and research network for the Haute-Normandie region. It is a regional network that connects the end users to the backbone and which is connected to RENATER in order to have national and international connectivity. SYRHANO2 is ATM based, with Cisco routers (7xxx) and Cisco switches (85xx).

The two networks are connected with a use of Cisco GSR12000 router (in RENATER) and Cisco 7500 router (in SYRCHANO2). The link speed between routers is 34Mb/s. Topology of the French testbed is presented in Fig. 10.

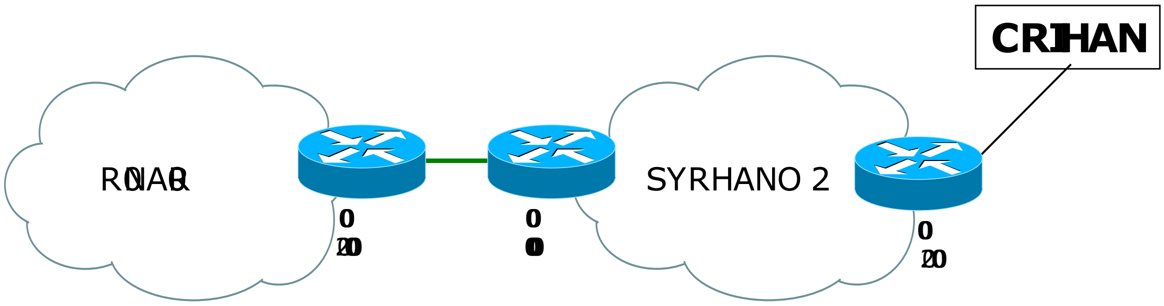

Fig. 10. French testbed topology.

Centre des Ressources Informatiques de Haute Normandie (CRIHAN) [11] will be connected to SYRHANO2 network, as the H.323 user. It is going to be connected to a Cisco 7200 router via a 34Mb/s link.

The H.323 equipment is composed of 2 Falcon IP from VCON, 1 Ezenia MCU and 2 Polyspan Viewstations 128.

As measurement equipment Smartbits generators will be used in French testbed.

7.3 H.323 test scenario

Stage 1

Prior to starting the tests all equipment along all paths used in the experiment in national testbeds must be configured. This stage requires a strong co-operation of the Sequin participants with the H.323 users in order to establish the traffic routes, the traffic type and the potential service quality requirements. For the co-operation purposes the representatives should be nominated from the participating testbeds and from each of the H.323 groups.

Stage 2

The second stage of the testing process will consist of the H.323 tests performed on the testbed created in Stage 1. These test should include transmissions with different qualities, i.e. including CIF (288x352 pixels) and QCIF (144x176 pixels).

The transmission quality measurements should include objective and subjective quality assessments.

The test procedure should involve using the two types of scenes [12]:

- Possibly a still scene (no motion) – to observe defects caused by the network itself.
  In this scenario the test picture (i.e. standard color TV test picture) would be transmitted and all the deformations and discrepancies observed. Such scenario allows for observation of much less significant and smaller picture defects.
- A motion scene.
  This scenario would involve a set of standard videoconference transmissions. These should be divided accordingly to the picture complexity and can include:
  - standard “news” (portrait-like picture of the speaker with static background),
  - enhanced “news” (portrait-like picture of the speaker with some moving elements in the background),
  - “live” transmission (moving camera and moving background, more than one speaker at a time, etc.).

The following test sequence is planned:

1. The network calibration measurements without H.323 traffic. This can be done with the use of standard measurement tools and the parameters may include: network delay, RTT, bandwidth and jitter.
2. The calibration of the videoconferencing tool. In this step the “best achievable” values of the video quality parameters would be established.
3. Initiation of the set of videoconferences between users in the involved networks. Two possible approaches should be considered:

3.1. Point-to-point connection - only a chosen pair of the participants should take part in the videoconference at the same time to simplify the procedure.

3.2. Multiple clients connected - all participants should take part in the videoconference at the same time.

4. Observation of the audio/video performance without QoS features enabled. Users should report their audio/video quality parameters.

5. Observation of the audio/video performance with enabled QoS features. At this stage IP Premium service will be enabled for H.323 traffic between the parties involved in tests. Then a videoconference will be initiated once more, exchanging the priority traffic.

During the tests the following possibilities on network load are planned:

a) Core load (i.e. GÉANT backbone load with a use of a "ping loop" to fill in the network).
b) Access from the NREN load.
c) Local Area Network load.
d) End station (PC) load.

All test configurations as well as the results should be precisely collected for future reporting.

During the results evaluation phase all data should be gathered and experiment summaries should be done by participants.

As suggested above, the QoS performance metrics will need to be measured end-to-end, or as close as possible to the users. These measurements should therefore be collected by the users or their applications must have means of providing this information, to complement the QoS perceived by the users. The networks will measure the QoS parameters on a per-hop basis and per-domain basis, including the amount of bandwidth allocated to Premium IP traffic and packet loss for Premium IP. A summary description of the tools to do this is available in section 9.

The testing activity involving H.323 users is closely related to the GÉANT deployment. The main condition for doing tests is the existence of the GÉANT connectivity for all NRENs involved in the tests as well as the GÉANT core router configuration. The tests were planned for November but there is a delay in getting their connectivity to the GÉANT network. Thus the tests will be done in December and results from the tests outlined in 7.3 will either be reported in Deliverable D6 or in an addendum to D5.1.

7.4 Expected results

There are a number of important aspects of the operational testing activity which are expected to be achieved:

- Validation of the operational model on production network. As the definition of IP Premium service became clear, the testing part of the project would focus on validation of different mechanisms supporting QoS and making use of the model on an international testing infrastructure.
- Verifying the correct coexistence of the two types of IP traffic: IP Premium and normal BE IP traffic
- Gaining experience in the service provisioning for real users. The significant outcome of the real users tests will be an experience with provisioning the Quality Of Service in a multi-domain, multi-technology environment, i.e. the set of activities need to be performed to satisfy user's request for QoS.
- Development of procedures for service ordering and implementation in multi-domain environment. As the provisioning of IP Premium service over an IP network is associated with the negotiation of service contract between customer and provider, a Service Level Agreement (SLA) model will be developed. The end-to-end SLA established during test will validate the specification defined in [13].

7.5 H.323 tests summary

The real users test case within the Sequin project will involve users from H.323 videoconferencing community, in particular the TF-STREAM Task Force. For the test purposes an international test network will be built to connect the involved parties. The testbed infrastructure will consist of four networks from France, Italy, Switzerland and Germany combining many domains, different transmission technologies and a number of equipment vendors. The international testbed described above and the suite of tests to be performed on the test network fulfils the requirements for the proving of concept of the Quality of Service definition defined in D2.1.

The testing activity on operational networks involving H.323 users is closely related to the GÉANT deployment. The main condition for doing tests is the existence of the GÉANT connectivity for networks of all parties involved in the tests as well as the GÉANT core router configuration. As there was a delay in connecting RENATER and GARR (which were connected to the GÉANT network at the end of November 2001) the results from the tests outlined in 7.3 will either be reported in Deliverable D6 or in an addendum to D5.1 provided later.

8 CO-OPERATION WITH THE IST PROJECT MOICANE

8.1 MOICANE project scope

The SEQUIN project will also make use of another international testing infrastructure, which will be composed from participants of European MOICANE project [14]. The tests with these users will be in particular the aim of WP6.

The basic idea of the MOICANE project is to create a "virtual laboratory" for services to be built with benefits for the European research community. While the other projects focuses mainly on the backbone section of the network, it addresses the integration of access and core parts with QoS issues. The project’s goal is to realise a distributed test-bed interconnecting several networks within Europe (in Portugal, Greece and Italy), which are characterised by different access technologies and supporting different services, such as tele-teaching, virtual-classroom, virtual-laboratory.

The project is based on creation of “virtual laboratory” concept, achievable through a scenario of network's collaboration. As today’s networks have strong demand for a variety of access technologies in order to extend service availability, transport capabilities of network backbone need to be enhanced in order to provide traffic with the appropriate Quality of Service.

Thanks to many initiatives to enhance the current architecture of IP-based networks, at least two architectural models have been defined: “Integrated Services over the Internet” – IntServ – and “Differentiated Services over the Internet” – DiffServ but the effectiveness of these solutions has not yet been thoroughly tested in real environments. That is why the MOICANE project aims at a complete integration of access and core parts, since the problems and QoS issues which arise from the access section may impair the whole network performance.

8.2 Project infrastructure

Four nodes will be deployed in a first phase: one in Portugal, one in Greece and two in Italy. Two more islands will be added in the second phase: in Greece and in Italy. The testbed have its main four nodes in Lisbon, Athens, Milan and Pisa as well as Bucharest. Each node consists of a core network domain and one or more access networks.

The project partner in Lisbon is INESC [15], which is connected to the Portuguese Academic and Research Network. The network node is at the University connected to RCCN [16] national network, which will be connected to GÉANT.

In Athens the partner is National Technical University of Athens - Institute of Communication and Computer Systems (NTUA-ICCS) [17] connected to GRnet.

The partners from Italy are CPR [18] in Pisa co-located with the University of Pisa and Flextel [19] in Milan.

The international connectivity will be provided by GÉANT where available. As a second solution, terrestrial dedicated connections will be used. Where none of the above solutions will be possible, the islands will be connected by legacy Internet

8.3 Tests

The time frame for tests with MOICANE project is February 2002. This part of work will focus on ensuring that the techniques tested previously (in laboratory tests as well as with H.323 users) deliver the requested QoS to the users. It will also refine the production of SLS/SLA documents. These issues will particularly fit into the scope of Work Package 6 of the Sequin project – Testing in User Environment.

The project participants are interested in offering IP Premium service between Athens and Milan or Pisa and between Milan (or Pisa) and Lisbon.

The node in Athens and in Lisbon could be easily connected to the national networks and this way to the GÉANT network. Although in case of connection of RCCN to GÉANT there will be only capacity issues on a direction from GÉANT to RCCN (RCCN will be connected via STM-4 link) resulting in implementing IP Premium service to send traffic **to** Lisbon. The connectivity between Milan, Pisa and GÉANT will be provided by GARR – the Italian national network.

9 MONITORING INFRASTRUCTURE AND TOOLS

Measurement equipment and traffic generation tools are key components for the testbeds. During the testing activity within the Sequin project the following four QoS parameters will be measured as defined in previous works in:

1. One-way delay
2. One-way IP packet delay variation (IPDV)
3. Packet loss
4. Capacity

As regards monitoring there are two main methodologies: active and passive. Active end-to-end measurements are mostly based on using a set of measurement tools where transmitters and receivers of measurement traffic are deployed. A transmitter injects artificial traffic into a link, network or device and a receiver provides results comparing data from both sides of the measurement system. For the above measurements the following tools could be used: RIPE TTM [20], Chariot [21] or Surveyor [22]. The metrics that can be measured by these tools are packet loss, one-way delay and jitter. For the last two metrics a precise clock synchronisation on both measuring sides is required (there is also an option of using NTP synchronisation).

Passive measurements are based on observing regular traffic. In this case counters on routers and Netflow mechanisms could be used. Such methods are suitable for average used capacity and packet loss.

The mixed solution is a better one, which consists of both passive and active measurements. Passive measurements are used for bandwidth and packet loss (router counters) and active measurement for delay and jitter (RIPE TTM). A system, which is capable of integrating both measurement techniques is *Taksometro* developed by DANTE.

Taksometro polls routers for bandwidth and packet loss on a per QoS tag basis. To widen its capabilities it is also possible to use an additional module to extract information from external active probes such as RIPE TTM. Taksometro provides simple and reliable data on a per-hop or per-domain basis, following the Diffserv model.

The measurements done by Taksometro are based on the following functionality:

- Capacity – measured on the input and output of each router interface
  - On Cisco routers with the CISCO-CLASS-BASED-QOS-MIB
  - On Juniper routers, “firewall filter” counters must be created (firewall MIB).
- Packet loss. Packets can be dropped on a device due to policing or congestion avoidance mechanisms e.g. WRED. Policing is done on the ingress interface of the network.
  - On Cisco routers with the CISCO-CLASS-BASED-QOS-MIB
  - On Juniper routers, counters created with policer. Value in the Juniper firewall MIB

- One-way delay and jitter (IPDV). The end-to-end delay is the sum of the delay induced by each domain on the path.

During the tests outlined in this deliverable the use of two types of tools is planned. The first one is going to monitor the performance of the test network a per-hop or per-domain basis and for this Taksometro will be used. The tool developed by DANTE will report packet loss as well as bandwidth. If one would like also to measure one-way delay and jitter (IPDV), other system capable to be precisely synchronised should be deployed in each domain e.g. RIPE TTM.

From the H.323 user's point of view, end-to-end performance can be monitored by the network only to a partial extent. Thus for measuring user visible metrics, tools associated with video-conferencing applications will be used or simply user's own perception.

RIPE TTM is a system capable of doing such measurements, but a few enhancements are necessary. The first one is a modification that allows setting the DSCP value for the traffic transmitted and then calculating the IPDV for a chosen class. In addition the performance values gathered by RIPE TTM system are kept in a central database at RIPE and could be accessed at least 30 min after measurements. Thus a second enhancement is needed to access data directly and immediately.

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11 ACRONYMS

ASIC	Application Specific Integrated Circuits
CAR	Committed Access Rate
CBWFQ	Class-Based Weighted Fair Queuing
ECN	Explicit Congestion Notification
GPS	Global Positioning System
ICMP	Internet Control Message Protocol
IP	Internet Protocol
IPDV	IP packet delay variation
LAN	Local Area Network
LLQ	Low Latency Queue
MDRR	Modified Deficit Round Robin
NREN	National Research and Education Network
NTP	Network Time Protocol
POS	Packet Over SONET
RED	Random Early Detection
RTT	Round Trip Time
SDH	Synchronous Digital Hierarchy
SLA	Service Level Agreement
SLS	Service Level Specification
TCP	Transport Control Protocol
TF-STREAM	Task Force - Real Time Multimedia Applications
TF-TANT	Task Force – Testing of Advanced Networking Technologies
UDP	User Datagram Protocol
WRR	Weighted Round Robin