

# *Project QUAdiS*

## Report of Activities

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### 1. Introduction

This report provides a short overview of the activities and of the main results carried out so far in the framework of the QUAdiS project.

Part 1 reports on the status of the experiment conducted in collaboration with CDF, FNAL and ESnet for the utilization of remote control applications when coupled with mechanisms for the support of quality of service (QoS) in packet networks. Experiments on the SRP protocol are detailed in Part 2.

Summary and conclusions are in Section 4.

### 2. Part 1: Remote control through the support of Quality of Service

Connectivity between the laboratories at CNAF and FNAL was established. As indicated in Fig. 1, connectivity is based on a two-hop connection. The first hop links the test router at CNAF to the ESnet test router located at FNAL. A constant bit rate (CBR) ATM permanent virtual circuit establishes a dedicated 2 Mbps connection through several research networks: GARR, TEN-155 and ESnet. Then, a local area network (FastEthernet) is used to connect the ESnet router to the FNAL test router, which is adjacent to the VME crate controller.

The test bed at CNAF is made of a Cisco C7200 router (the end-point of the ATM connection), of a Linux workstation (the client running the Robin software necessary to interact with the remote VME controller) and of a set of additional Sun workstations needed to inject low-priority background traffic. The test bed at FNAL is composed of one Cisco C7200 router, the VME controller and of an additional Silicon Graphics test workstation used as traffic generator.

Baseline measurement of Round Trip Time (RTT), packet loss, TCP and UDP throughput are currently in progress.

### 3. Part 2: Testing of LAN optical transmission technologies

A three-node SRP local area network was set-up as illustrated in Fig.2. Three routers are connected through DPT interfaces at 622 Mbps to form a single IP subnet. Each node of the two-ring network is connected to a set of local hosts through FastEthernet or GigaEthernet interfaces depending on the interfaces available on the router. The router CISCO 12000 has one GigaEthernet interface and it was connected in GigaEthernet interface to a pool of workstations through a Catalyst 6506. On the other hand, both router C7500 and C7200 were connected in FastEthernet mode to the SmartBits 200, a traffic generator by Netcom Systems used for one-way delay and recovery time measurement.

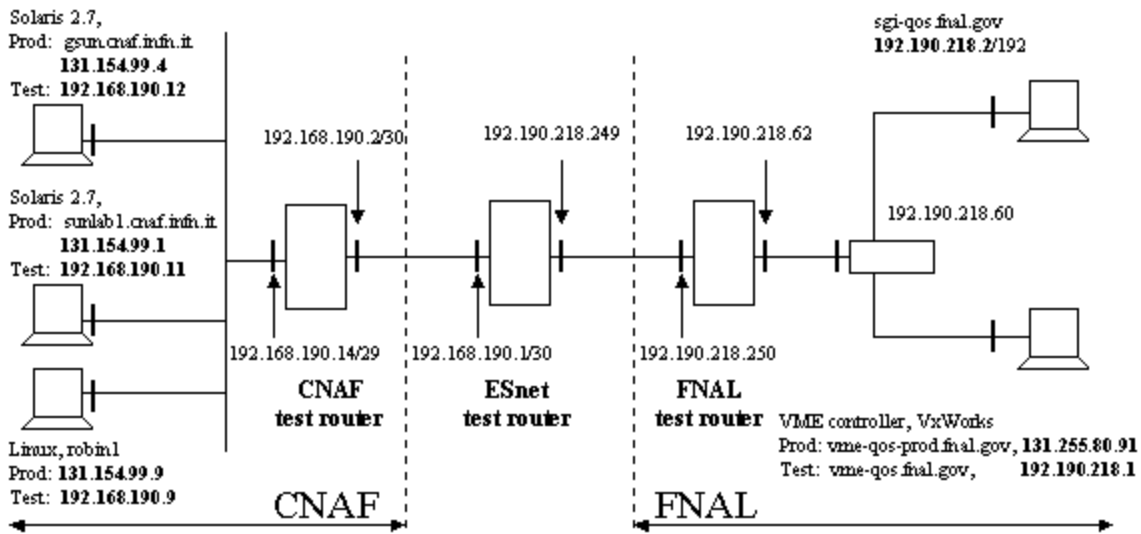


Fig. 1: test bed for remote control testing

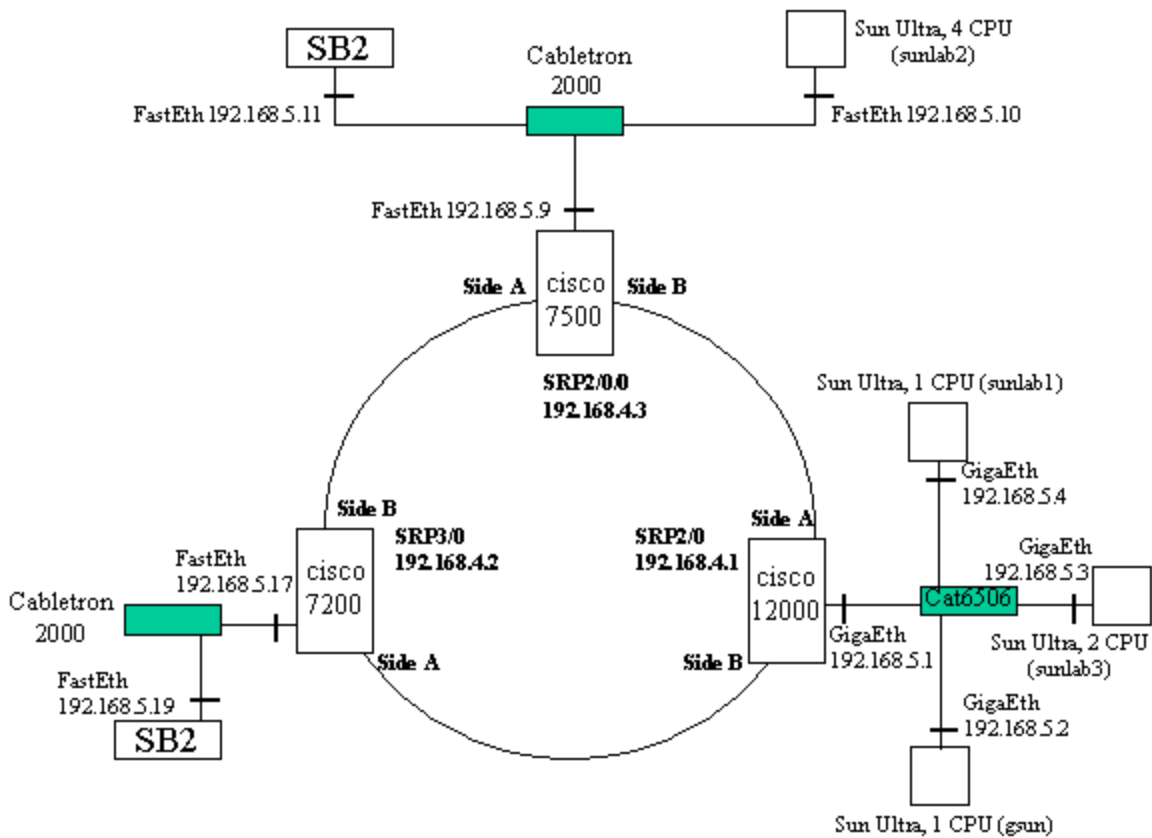


Fig. 2: SRP local area test bed

Four different tests were carried out:

1. recovery-time measurement,
2. SRP performance measurement as a function of traffic load,
3. CPU load measurement,
4. one-way delay and instantaneous packet delay variation measurement.

In the following paragraph we will summarize the main achievement of each test.

## **Test 1: Recovery time**

### Summary

In this context we refer to *recovery time* as the time need by the SRP protocol to re-establish layer-3 connectivity in the SRP ring after a ring failure (hard failure, like signal fail, or software failure, like signal degradation). Recovery time depends on the diameter of the ring and the maximum recovery time is 50 msec. With this test we measured the actual recovery time in our topology. According to our measures, in our simple test bed recovery time varies in the range [10, 13] msec in case of wrapping of the SRP interface, while it's only 2 msec in case of loss of signal.

### Results and test methodology

The recovery time was estimated by injecting a continuous constant bit rate UDP stream with known inter-packet gap  $G$  through. The stream is injected by the SmartBits 200, which gives the possibility to finely set parameter  $G$  and produces a log file in which the sequence number of lost packet is indicated.

Hardware and software failures are discovered through IPS (Intelligent Protection Switching) probes. IPS is a protocol for automatic healing after hardware and software failure like in SONET/SDH rings, based on proactive fault monitoring and fault reporting. A given side of a SRP interface enters the *wrapping* state to bypass the failed portion (fibre or node) of the ring.

Two kinds of different failure are simulated:

1. *command-driven wrapping of the SRP interface*: a failure is instantaneously notified to the router; the neighbour router on the other side of the fibre has to discover the loss of connectivity and then wrap the right side of the SRP interface).

The command used to wrap the interface is:

```
srp ips request forced-switch
```

2. *loss of signal* : this failure was produce through the disconnection of one couple of one cable. The failure of a single ring is notified immediately to the two routers on both sides; then, the ring corresponding to the other fibre is disabled and the wrap operation is executed

At the IP layer the effect of one failure is the loss of a train of  $n$  consecutive packets. The recovery time is estimated according to the formula:  $n * G$ .

## **Test 2: Traffic Load**

### Summary

Our study focused on the following aspects:

1. router capability of injecting traffic on both sides of the SRP interface at the same time. This aspect is one of the main advantages of the SRP protocol: when sending traffic at the same to

different nodes of the ring, in case of no contention on the ring traffic can be sent at the same time on both sides of the interface. This increases capacity utilization on the ring.

2. capability of reaching link saturation on a given side of the SRP interface;
3. performance of the GigaEthernet interface of the router C12000.

According to our test results, one SRP node (C12000) can successfully load both sides of the SRP ring when sending traffic to two distinct routers (C7200 and C7500) reachable from different sides of the ring, as illustrated in Fig. 3. In addition, by sourcing traffic from the GigaEthernet interface the C12000 could saturate on SRP branch. However, in this case given the limited capacity of the internal bus and of the CPU of the SRP interface of the C7500 and of C7200, massive packet loss occurred in both routers. The maximum amount of traffic which could be injected by the GigaEthernet interface is approximately 900 Mbps.

Results and test methodology

In order to produce the maximum traffic load in the SRP, traffic was injected from 4 different workstations connected with GigaEthernet interface to the Catalyst 6506. Router C1200 was the transmitter since in our test bed it's the only router in which the input interface capacity could exceed the capacity of one SRP branch (622 Mbps). Traffic was sent by router C12000 to router C7500 and C7200.

When the SRP link capacity is exceeded, then the counter of "ignored" packets increases considerably and steadily, where packets are counted as *ignored* if "the interface hardware ran low on internal buffers. These buffers are different than the system buffers [...]. Broadcast storms and bursts of noise can cause the ignored count to be increased."

The deployment of three workstations SUN didn't suffice to reach the maximum input throughput of 900 Mbps: a fourth workstation had to be added.

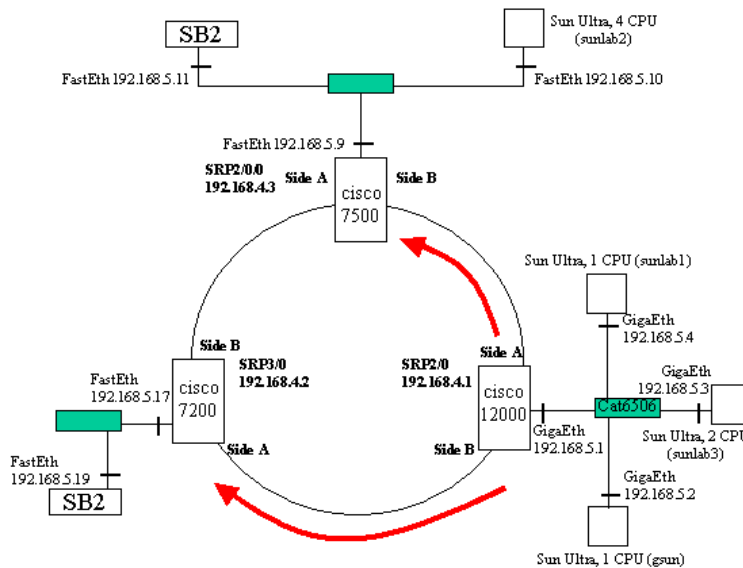


Fig.3: traffic load on two branches of the SRP ring

**Test 3: CPU load**

Summary

Because of the limits in CPU and bus capacity of router C7500 we could estimate the CPU load as a function of traffic only for rates approximately up to 350 Mbps.

### Results and test methodology

We have measured the average CPU load of the SRP interface of router C7500 as reported by the router (the average is computed over a 5 minute time interval). When the CPU is saturated the phenomenon of packed loss appears. As shown in Fig.4, apart from a few discontinuity points the CPU load curve increases with the amount of input traffic.

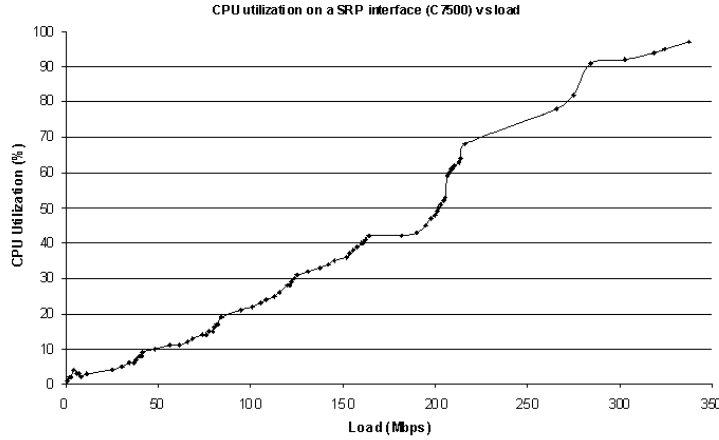


Fig.4: CPU load of the SRP interface on router C7500

### **Test 4: One-way delay and instantaneous packet delay variation**

#### Summary

The measurement of one-way delay and instantaneous packet delay variation (IPDV) in a SRP network is important for the evaluation of the efficiency of the SRP protocol, in particular in comparison with similar performance results in local area networks based on the GigaEthernet technology.

With 64 by packets one-way delay measurement points are mainly concentrated in the range: [75.2, 238]  $\mu$ sec, as shown in Fig. 5: one-way is limited but still greater than one-way delay when measured between two end-systems connected through the FastEthernet ports of a LAN switch – when the two end-systems are either placed in the same virtual LAN (VLAN) or in different VLANs - .

Also IPDV is limited and mainly concentrated in the range: [24.2, 106.2]  $\mu$ sec (Fig. 6).

#### Results and test methodology

*One-way Delay* is defined formally in RFC 2679. This metric is measured from the wire time of the packet arriving on the link observed by the sender to the wire time of the last bit of the packet observed by the receiver. The difference of these two values is the one-way delay.

*Instantaneous Packet Delay Variation (IPDV)* is formally defined by the IPPM working group Draft. It is based on one-way delay measurements and it is defined for (consecutive) pairs of packets. A *singleton* IPDV measurement requires two packets. If we let  $D_i$  be the one-way delay of the  $i^{\text{th}}$  packet, then the IPDV of the packet pair is defined as  $D_i - D_{i-1}$ .

According to common usage, IPDV-jitter is computed according to the following formula:

$$\text{IPDV-jitter} = | \text{IPDV} |$$

In our tests we assume that the drift of the sender clock and receiver clock is negligible given the time scales of the tests. In the following we will refer to IPDV-jitter simply with *IPDV*.

The frequency distribution functions plotted in both Fig. 5 and 6 are computed over a population of 5000 samples. The packet stream the measurement refers to is a UDP constant bit rate flow at 1 Mbps. The stream was sourced from one FastEthernet interface of router C7500, forwarded across the SRP ring and received by the FastEthernet interface of router C7200.

Both FastEthernet interfaces of SmartBits 200 were connected back-to-back to the C7500 and C7200 respectively.

One-way delay and IPDV were computed over the same sample population.

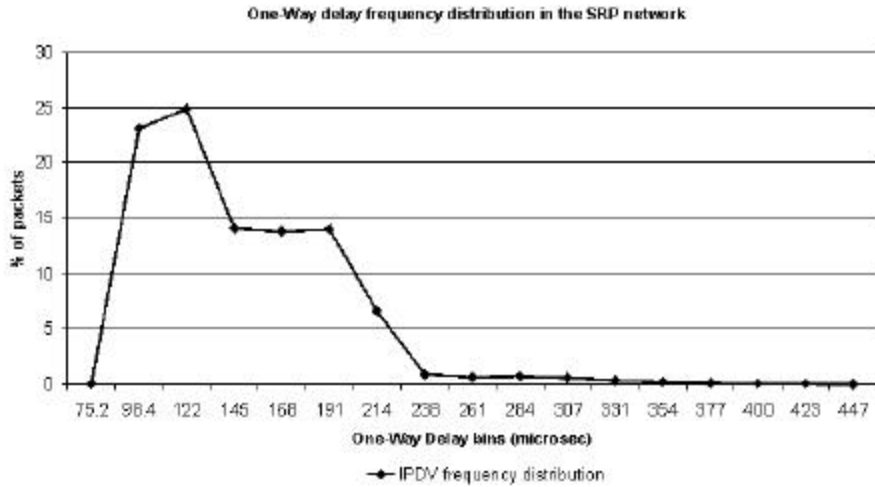


Fig.5: one-way delay frequency distribution in a 622 Mbps SRP ring

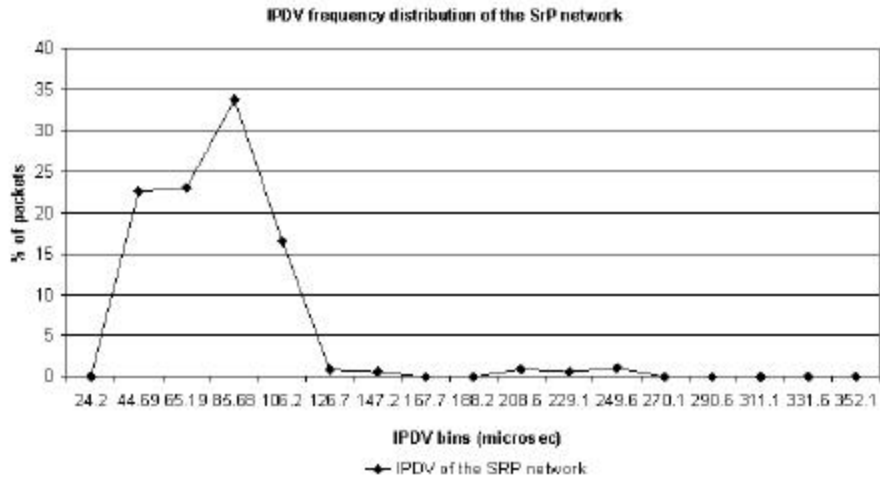


Fig. 6. IPDV frequency distribution in a 622 Mbps SRP ring

#### 4. Summary

Remote control:

- establishment of the end-to-end connectivity between CNAF and FNAL, test of connectivity in progress

SRP:

- very limited recovery time
- establishment
- optimal utilization of capacity in the ring according to protocol specifications

- small delay and IPDV but still greater than in a FastEthernet LAN, more investigation needed, for example extended to a GigaEthernet scenario
- complete utilization of the ring capacity (622 Mbps of actual traffic load on a SRP branch was possible)
- limits in the existing test bed: because of limited CPU and bus capacity at routers C7500 and C7200 the performance (CPU load, throughput, delay and IPDV) at full speed on both directions of the SRP couldn't be tested.

## Acronyms

ATM	Asynchronous Digital Hierarchy
CBR	Constant Bit Rate
IPDV	Instantaneous Packet Delay Variation
IPS	Intelligent Protection Switching
QoS	Quality of Service
RTT	Round Trip Time
SRP	Spatial Reuse protocol
TCP	Transport Control Protocol
UDP	Unreliable Data Protocol
VLAN	Virtual LAN