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Abstract:

This document is a preliminary specification of the IPv6 Quality of Service (QoS) tests that will be carried out by the various partners in 6NET. We describe the QoS testbed infrastructures of the various partners and the tests that will be performed. The majority of the tests will be concerned with the provision of Differentiated Services both within the partner networks and between partner networks across 6NET.

Keywords:

QoS, IPv6, Mobile IPv6, tests, Intserv, Diffserv,

Executive Summary

Activity 4.4 of 6NET is concerned with IPv6 Quality of Service (QoS). This deliverable, the first within the activity, is a preliminary specification of the QoS tests that will be carried out by the various partners in 6NET. Initially, each partner will conduct IPv6 QoS tests on their local testbed infrastructure. Once these initial phases are completed, further QoS tests between partners across the 6NET infrastructure are anticipated.

The majority of the tests will be concerned with the provision of IPv6 Differentiated Services. In particular, attention is being given to the provision of EF (Expedited Forwarding), AF (Assured Forwarding), LBE (Less-than Best Effort) and BE (Best Effort) based services; their interactions and appropriate configuration and tuning of router resources.

In addition, the provision of Integrated Services using RSVP in a Mobile IPv6 environment will be studied.

At this stage, the exact nature, timing, organisation and implementation of the IPv6 QoS tests across 6NET cannot be explicitly defined. These will become more clear as the activity progresses, inter-partner collaborations are formed and procedures for IPv6 QoS testing across 6NET are better understood.

Table of Contents

1 Introduction

Over the last decade, the tremendous growth of the Internet has transformed its original character as a simple communication medium enabling remote computing, file transfer and email exchange to one of a global telecommunications infrastructure that is required to support a full taxonomy of existing and emerging applications. This rather heavy and technologically complex burden was not part of the Internet's fundamental design philosophy. As such, the Internet of today is simply not suited to supporting the tomorrow's new breed of applications and user demands. It is therefore imperative that the next generation Internet implemented through IPv6 can also provide the necessary Quality of Service (QoS) to support the requirements of tomorrow's applications.

The design principle of the Internet and its underlying communication protocol, the Internet Protocol (IP), is based on a packet switching model in which individually addressed packets are forwarded on a best effort basis. That is, the network provides no guarantee to how quickly a packet will be delivered to its destination, if at all. The virtual circuit service offered by TCP provides for guaranteed delivery of data but does not address parameters such as packet latency, jitter or data rates (bandwidth) that the new emerging multimedia applications are sensitive to. The new breed of multimedia applications require significant amounts of bandwidth; even when using compression techniques such as MPEG.[1] In addition, some multimedia applications, especially those involving conferencing or IP telephony, have strict timing requirements. Round trip delivery delays above 500 ms can make them unusable. It is therefore necessary for the Internet to provide Quality of Service if it is to satisfy the requirements of these new applications.

Since the current Internet service of BE (Best Effort) cannot provide for such demanding application requirements, the IETF defined two broad QoS paradigms: Integrated Services (Intserv) [1], which employs a resource reservation mechanism (most commonly RSVP [2]) for applications to reserve network resources and Differentiated Services (Diffserv) [3], which uses packet marking in order to differentiate between traffic classes.

The majority of the IPv6 QoS tests will be concerned with the provision of Differentiated Services. Particular attention is being given to the provision of EF (Expedited Forwarding), AF (Assured Forwarding), LBE (Less-than Best Effort) and BE (Best Effort) based services; their interactions and appropriate configuration and tuning of router resources. However, the provision of Integrated Services using RSVP in a Mobile IPv6 environment will also be studied.

Initially, each partner will conduct IPv6 QoS tests on their local testbed infrastructure. Once these initial phases are completed, further QoS tests between partners across the 6NET infrastructure are anticipated.

The remainder of this document describes the QoS infrastructure and test plans of CSC/Funet, CTI, RENATER/ENST, ETRI and Lancaster University.

[1] An average MPEG video stream is likely to require bandwidth between 1.35 Mbps (375 x 288 at 25 frames per second for MPEG-1) and 6.5 Mbps (720 x 480 at 30 frames per second for MPEG-2) or more if higher quality is desired.

2 CSC/Funet

2.1 Testbed

Our local testbed consists of three Cisco routers (one 7200 VXR and two 7500), one Juniper M20 router and Linux test PCs. These devices can be connected with Fast Ethernet, STM-1 POS, Gigabit Ethernet or ATM links.

The current test setup is depicted in Figure 1.

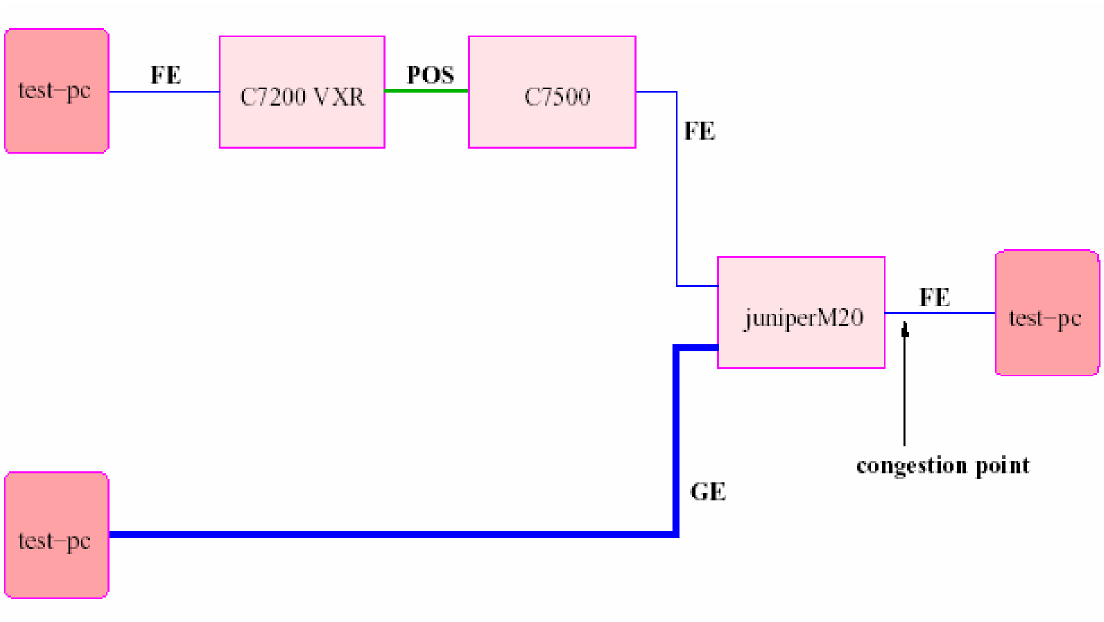

Figure 1 CSC/Funet Testbed

The IOS running in test devices is Experimental Version 12.2(20020828:102445). This version has several QoS features implemented in IPv6. The JunOS versions during the test were 5.3R2 and 5.3R3.

2.2 Tests already done

We have tested the QoS/IPv6 features of Cisco and Juniper including:

- Cisco:
    - classification, marking
- Juniper:
    - classification, queuing

- - LBE configuration and functionality testing

To generate the test traffic (TCP and UDP traffic) we have been using the Iperf program [4].

2.3 Planned tests

In the near future we are planning to do tests in the Funet production network. We have IPv6 implemented in six of our backbone routers, and we are going to expand this topology.

The possible test topology in the production network is depicted in Figure 2.

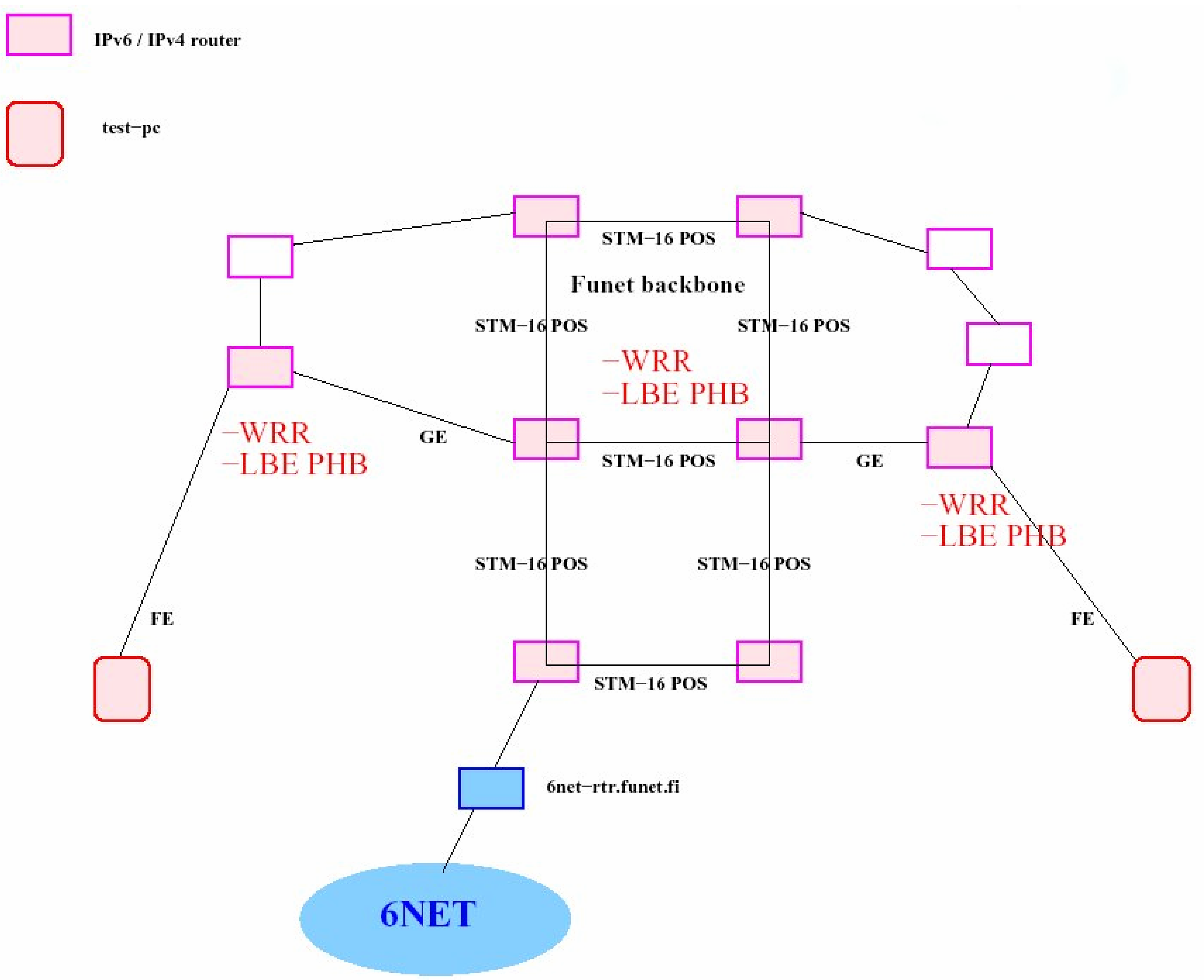

Figure 2 Test Topology in Funet Production Network

We have Linux test PCs sited in six of our PoPs, and these devices can be used to generate and receive test traffic.

The main focus of testing will be on the LBE traffic class. We want to study the BE traffic performance in the presence of LBE marked traffic.

At the moment, we are in a stage of starting to configure LBE in Funet backbone. We are also interested in test activities with other 6net partners, but this may only be possible later in the project once we are ready with our own tests.

3 CTI

Our proposal is to try some tests with the DiffServ architecture. At first, these will be on the Greek part of the 6NET network, which is presented in Figure 3. After this phase, it would be useful to perform some extra tests in cooperation with other 6NET partners.

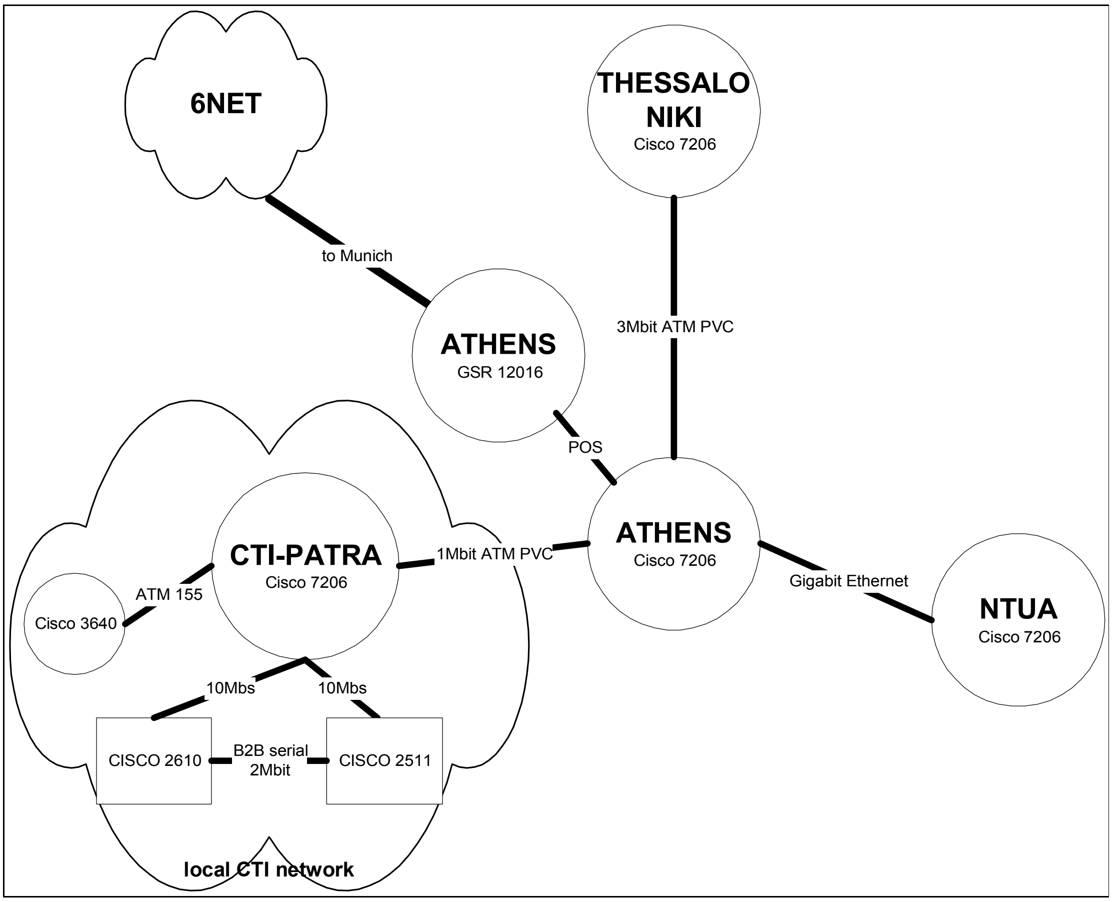

Figure 3 CTI Testbed

3.1 CTI QoS Experience

Our experience is with Expedited Forwarding and Assured Forwarding services. This consisted of theoretical jobs and a large number of simulation tests on a network simulator. The first objective was to study and describe the gold service (EF based service) on an IPv4 network. The traffic on the simulation tests consisted of gold traffic from various applications and background traffic. The latter corresponding to real traffic on the Internet, and was treated by the best effort service. The simulator that was used was the Network Simulator 2 (NS-2) [10] with some modifications and changes for our needs [8]. Our previous work also includes tests on an AF based service, called *relative*. It was a proposal for a service with better performance than best effort. AF traffic is classified as *in profile* if it complies with the initial agreement between the client and the provider, where the client specifies his traffic characteristics and as *out of profile* if it violates that agreement. The main idea of relative service is to forward the in-profile packets with very small dropping probability. The out of profile packets are treated differently, with a larger dropping probability.

The following methods were used in the testing scenarios:

- **Classification:** using the DSCP field of IPv4 header
- **Policing:** using the Token Bucket Policy
- **Action:** all out of profile packets are dropped
- **Queuing:** have been used several methods, Priority Queuing, Weighted Fair Queuing (WFQ) or Modified Deficit Round Robin (MDRR-CISCO mechanism available on series 12000)
- **Queue management:** using RED and WRED method

Generally, our previous work [8] was concentrated on EF and AF based services and on testing them on a simulation environment.

3.2 Proposal for the IPv6 QoS tests of 6NET

Our proposal for the QoS activity of 6NET is to try to provide EF based services on the Greek part of the 6NET network. Later, these tests can be extended on the whole 6NET network with the cooperation of other partners. The main objective is to use our experience and move from a simulation environment to a real network. According to our schedule, the tests will begin with the gold service, which can be used from applications like Voice over IP, H323 applications etc. The basic idea of gold service is that all the in profile packets must arrive to the destination, with the minimum possible delay and jitter. The out of profile packets may arrive or not, depending on the network's status. All the above parameters must have assigned to a service level agreement between the network provider and each client. The traffic that will use the gold service will be that generated by the OpenH323 application (H.323 videoconference), which have been ported to IPv6 networks [9] in the contents of Work Package 5, Task 5.1 of 6NET.

A second stage could be to provide AF based services too, like relative service. After that, our intention is to perform some QoS tests with other partners.

The QoS mechanisms that will be used (and are supported by the network devices of our topology) on this implementation are summarized in the following points:

- Token Bucket Policy on edge routers
- Priority Queuing, Weighted Fair Queuing
- RED and WRED mechanisms for queue management
- Classification using the DSCP on Traffic Class field of IPv6 header.

The entire proposal can be summarized in two stages. First, the planed tests will be performed on the local CTI experimental network. Second, the tests will be continued on the entire Greek network of 6NET. The testing plan is described in the following points:

- The first tests will try to configure and test the gold service. This service can guarantee delay, jitter and packet loss. Its use is generally for real time applications and our decision is to use it on H323 traffic. The OpenH323 application, which has been ported to IPv6 networks [9], will be used for this purpose. The testing scenarios are presented in the next section.

- After the above phase, the QoS tests will be continued, adding one more class of service. In particular, the class(es) will have worst treatment than the gold service but better than best effort.

In addition, a third stage could perform some QoS tests with other partners. However, this will only be possible after the completion of our proposed tests.

3.2.1 Phase 1 testing scenarios on gold service

In the first phase, the objective is to configure and calculate the performance of the gold service. First, some tests will be done to configure the routers for that service on the local experimental network, as shown in Figure 3. These tests will then be continued to inspect the performance of the service. Background traffic will be created on the links, using Lan Traffic v2 [11] and gold service traffic will be produced by the OpenH323 application.

After this phase, the tests will be moved to the 6NET network in Greece to take real results. It is planned to use a powerful PC directly connected to the 7206 Cisco router at CTI and a second PC connected to the 7206 router at Thessaloniki. According to this topology, there are two backbone links; the first has 1 Mbit capacity and the second 3 Mbits. The LanTraffic v2 application will create best effort background traffic to fill these links. Gold service traffic will be created by the OpenH323 application. Since the gold service traffic must be an aggregate of flows, it is sensible to open various videoconference sessions between the two 7206 routers, to simulate flow aggregation. The mechanisms that will be used are the following:

- Classification at the edge router according to the ports used by the OpenH323 application
- Policing at the edge router using the token bucket mechanism. The token bucket profile will be configured online and is a point for research. From bibliography, the theoretical configuration is: CIR a little bigger than the expected bandwidth of the aggregation flows and depth a few packet so as to manage packet bursts.
- Queue management. At each router there will be two queues, the first will serve the gold service and will be the priority queue. The second will serve the best effort traffic. The packets that are out of profile will be served as best effort traffic.
- Finally, RED will be used at the best effort queue for congestion avoidance.

The characteristics that describe the performance are packet loss, packet delay and jitter. These can be calculated by the OpenH323 application. The background traffic that will be created by LanTraffic v2 will simulate real traffic on a network. Particularly, the TCP- UDP analogy and the packet size will be configured according to that in a real network.

LanTraffic v2 can create and manage at most 32 simultaneous IP connections (TCP or UDP). It gives the opportunity to configure the TCP parameters such as TCP buffer size and TCP window size and can produce many statistics. It allows the configuration of many parameters to the IP connections such as IP address, port number, protocol and packet size. Our proposal is to fill the bi-directional links with background traffic, which will be treated with best effort service. The link utilization should be at or near 90% and the packet size should be 40 bytes, 552 bytes and 1500 bytes. The analogy for each size is 59%, 32% and 9% [6]. Besides the TCP and UDP packets analogy should be 70% and 30% respectively.

The expected results from this phase are a first view of the performance of the gold service (OpenH323) on a real network, the way it changes according to configurations changes on the routers and the impact of the token bucket profile settings to the whole performance.

3.2.2 Phase 2 adding one more class of service

After finishing the tests for the gold service, it is planned to perform some other tests adding one more class of service. This class has been chosen to be between the gold service and the best effort service. Its role will be to serve some packets better than best effort. The testing scenarios will be the same as above, with the difference that the LanTraffic v2 will produce the traffic flows for that service. The mechanisms that are planned to be used, except from the corresponding for gold traffic are:

- Classification at the router according to the port numbers.
- Policing at the edge router using the token bucket algorithm.
- Queue management. Three queues will be used: gold, best effort and one more, which will serve packets with more weight than the best effort. This step could be achieved with the use of Weighted Fair Queuing.

The objective of the second phase is to understand the possible performance of the added class of service, the way it should be configured and the inspection of the token bucket profile for the service so to understand the way it should be policed.

3.2.3 Phase 3

This phase will be defined in the future and will consist of QoS tests performed in cooperation with other partners.

4 ETRI

Asia and Europe are forging ahead towards the information age by vigorously promoting a knowledge-based economy. Rapid progress in information and communications technology, including the emergence of the Internet, is providing a bonanza of opportunities for new cooperative endeavours between the two regions. Facilitation of speedier exchanges of knowledge and information, and trade expansion through the utilization of Asia-Europe Information Infrastructure are among the fruits to be harvested from such endeavours. Since its inception in 1996, ASEM has underscored intellectual exchanges between Asia and Europe. At ASEM I held in Bangkok in 1996, it was agreed to promote "intellectual exchanges between Asia and Europe" and to establish networks among appropriate individuals and organizations from both regions. By facilitating the exchange of information between the two regions, the present proposal for a Trans-Eurasia Information Network Project promises to be a useful vehicle for promoting closer ASEM cooperation.

4.1 ETRI's IPv6 Network Topology

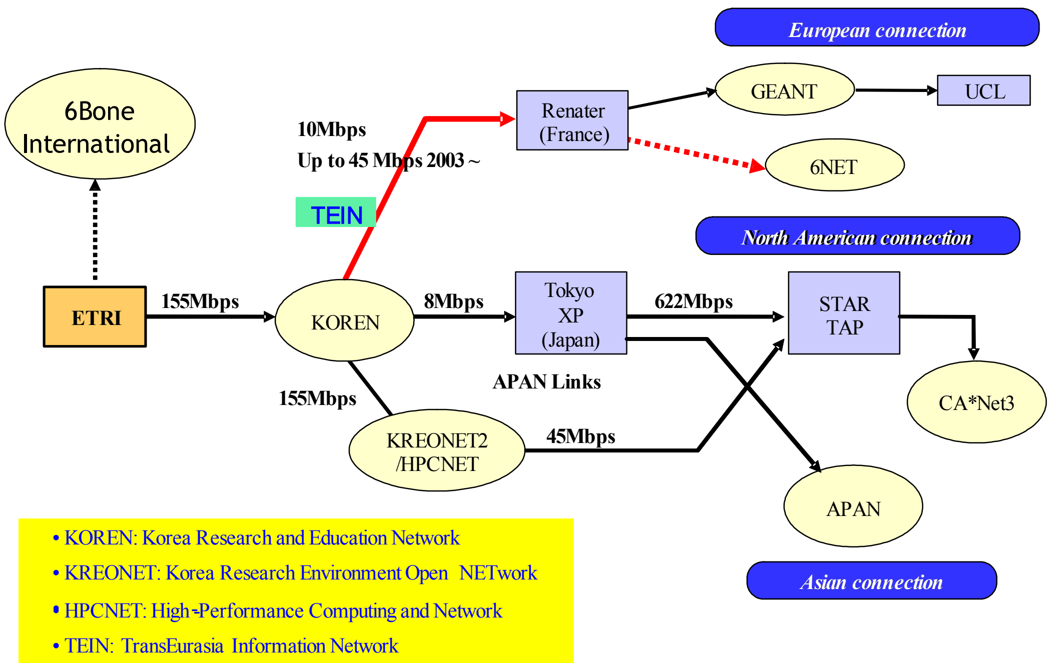

Figure 4 ETRI External Connections

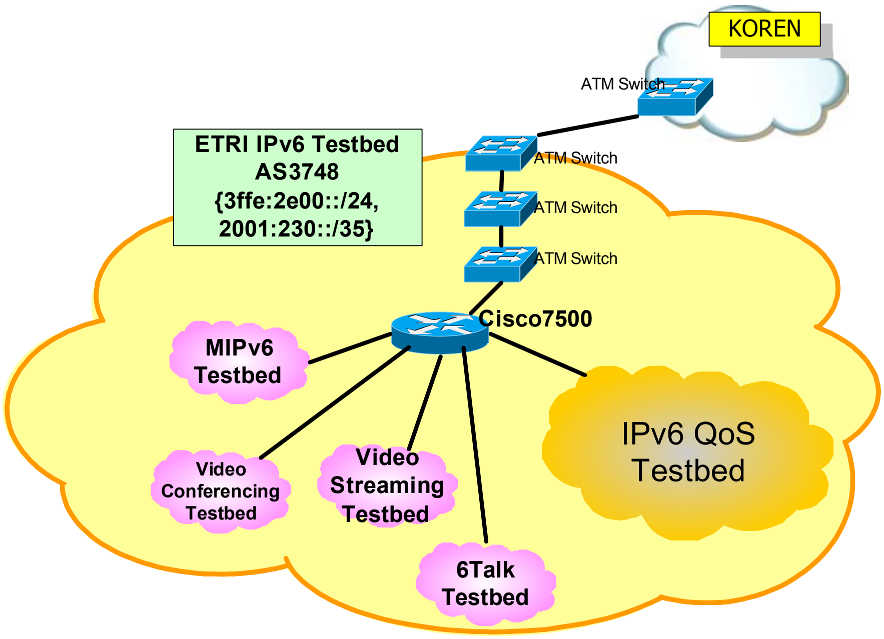

Figure 5 ETRI Internal Topology

4.2 IPv6 QoS Testbed

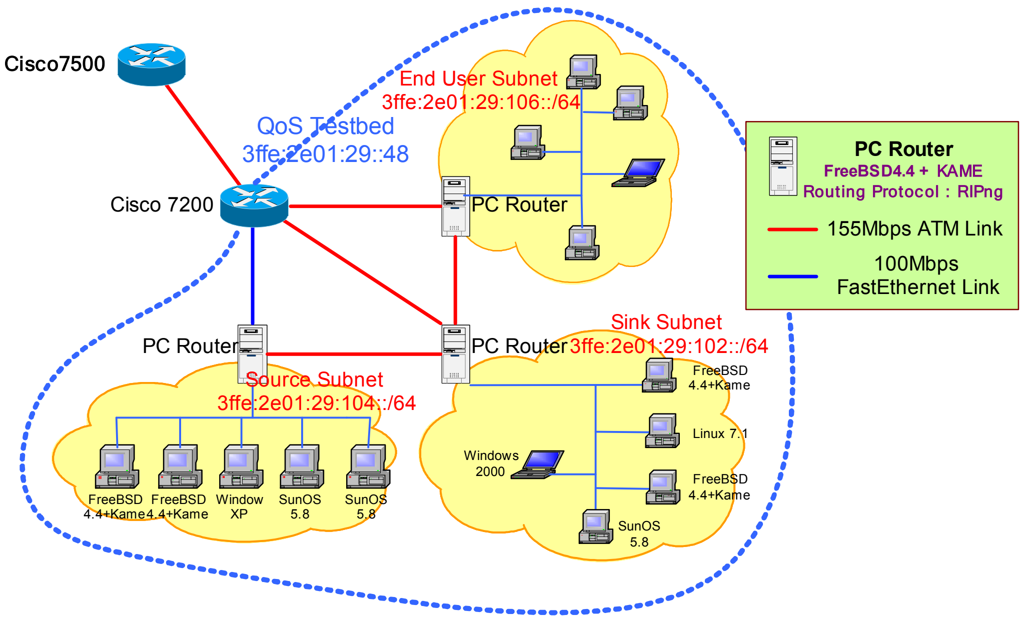

Figure 6 ETRI QoS Testbed Topology

Equipment for QoS testbed:

- Fore ASX200 ATM Switch : 2EA

- Cisco 7204 Router : 1EA
  - Ports : 2 Fast Ethernet, 1 155Mbps ATM
  - IOS : 12.2(2)T
    - It will be upgraded to EFT version for the IPv6 QoS test until the end of Sep.
- PC Router : 3EA
  - CPU : Intel Pentium Ⅲ 1 GHz, 256 M Ram
  - OS : FreeBSD 4.4 + KAME Snapshot
  - Queue Control : ALTQ 3.1
  - Routing Protocol : RIPng, Static

Tools:

- Tele Traffic Tapper : http://www.csl.sony.co.jp/person/kjc/kjc/software.html
- MGEN6 : http://matrix.it.uc3m.es/~long/software.html
- Netperf : http://www.netperf.org/netperf/NetperfPage.html

We have tested IPv6 QoS within the ETRI's QoS testbed. In this section, we will introduce the QoS test experience briefly.

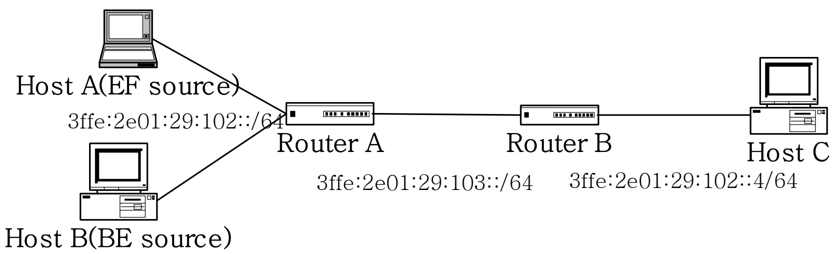

Figure 7 ETRI Test Topology

Host A sends EF traffic to host C and host B sends BE traffic. Classification and marking the traffic class are done in router A by host's address . Router A enqueues the marked traffic to each class queue which uses the CBQ mechanism. Router B only classifies the traffic by traffic class marked by Router A and sends the traffic to the output queue. Host C opens two ports for EF traffic and BE traffic are wait traffic.

4.2.1 Policy in Routers

Route A:

- Classification
  - By host address
  - The traffic from host address 3ffe:2e01:29:102::2 is classified to EF traffic and marked by 0xB8 with traffic class field of IPv6 header.

  - The traffic from host address 3ffe:2e01:29:102::3 is classified to BE traffic and no action is processed in this traffic.
- Metering
  - Token Bucket Meter for EF traffic
  - Token Rate = 3 Mbps, Bucket Depth = 256 KBytes
- Action
  - Out of profile packet is dropped
  - In profile packet is marked with 0xB8 in traffic class field
- Queuing
  - CBQ
  - 3Mbps for EF traffic
  - 7Mbps for BE traffic

Route B:

- Classification
  - By DHCP
- Metering
  - Token Bucket Meter for EF traffic
  - Token Rate = 3 Mbps, Bucket Depth = 256 KBytes
- Action
  - Out of profile packet is dropped
  - In profile packet is passed to EF Queue
- Queuing
  - CBQ
  - 3Mbps for EF traffic
  - 7Mbps for BE traffic

4.2.2 Test scenario and test tool

Test tools:

- Mgen6 : This tool generates IPv6 traffic in rates and packet size specified by user
- Drec6 : This tool is included in Mgen6 and it received traffic generated by mgen6. Also it calculates the speed and loss and delay variation.
- TTT(Tele Traffic Tapper) : This tool monitors the link and plots the graph according port number and address.

4.2.3 Test Scenario and results

2Mbps EF Traffic and 6Mbps BE Traffic:

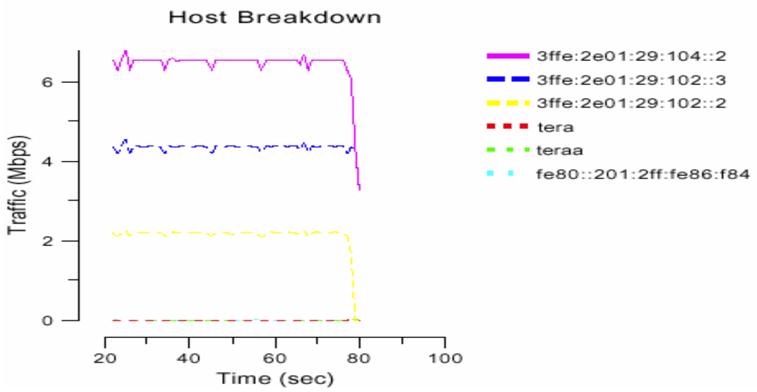

Figure 8 2Mbps EF Traffic and 6 Mbps BE Traffic

As the link capacity is 10 Mbps and total generated traffic is 8 Mbps, no loss has occurred.

3Mbps EF Traffic and 10Mbps BE Traffic:

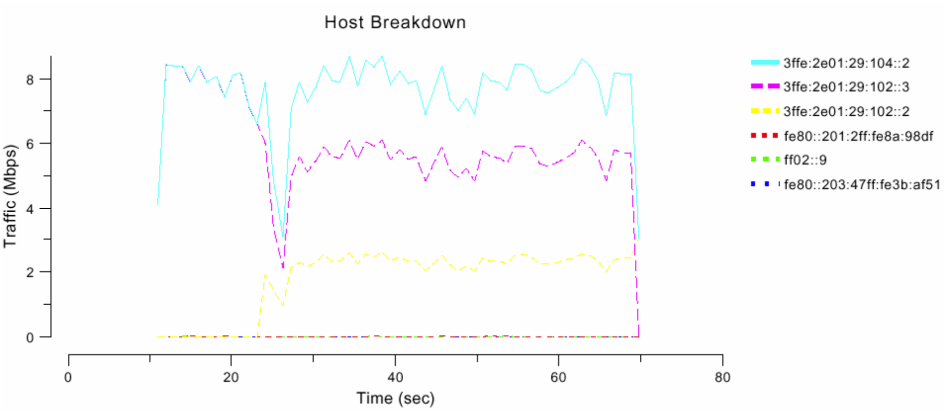

Figure 9 3Mbps EF Traffic and 10 Mbps BE Traffic

During first several seconds, as host B only generates 10 Mbps and there is no EF traffic, so BE traffic use the bandwidth allocated to EF traffic.

At 25 sec, host A start to generate 3 Mbps EF traffic. EF traffic is protected but BE traffic use 7Mbps bandwidth.

5Mbps EF traffic and 10 Mbps BE traffic:

During first several seconds, as host B only generates 10 Mbps and there is no EF traffic, so BE traffic use the bandwidth allocated to EF traffic.

At 25 sec, host A start to generate 5 Mbps EF traffic. EF traffic is allowed up 3 Mbps, so excess EF traffic is dropped in route A by token bucket meter with 3Mbps token rate and 256Kbytes bucket depth.

4.3 Discussion

What kind of Traffic Class and Code Point?

- First, we want to test only EF traffic and BE traffic. If these tests succeed, it will be good to test other services.
    - EF code point : 0xB8
    - BE code point : 0x00

Queuing Type: We will apply CBQ (Class Based Queuing) or PRIQ (Priority Queuing).

- Other queuing algorithms are possible.

Policy :

- TBD

Test tools :

- Round trip time → ping
- Loss → mgen6
- Delay variation → mgen6

5 RENATER/ENST Bretagne

RENATER, the French national academic network, participates in WP4 for QoS testing with the collaboration of ENST Bretagne, a leading education and research institution in telecommunications and networking. The tandem has worked in similar projects, both at the European and the national levels.

In Europe, RENATER and ENST-B have participated in the QoS activities of Terena's TF-NGN. Terena is a consortium of Europe's national academic and research networks. TF-NGN is the Terena technical task force dedicated to research on and testing of new networking technologies.

In France, RENATER and ENST-B participate in projects like the VTHD (Really Very High Speed) experimental network and the G6, a national association dedicated to promote research, test and deployment of the IPv6 protocol suite.

5.1 Objectives

- Gain experience in the utilization of QoS mechanisms over IPv6.
- Configure available mechanisms for achieving conformance to DiffServ standardized PHBs.
- Evaluate performance of QoS mechanisms based on experimental measurement of relevant metrics under different traffic conditions.

5.2 Summary

In general, QoS testing involves setting up mechanisms in hosts and routers, sending traffic with predefined and varying profiles, and recording metrics of interest using the appropriate measurement tools. The following list summarizes these elements:

- Mechanisms to evaluate (based on available platforms)
  - Conditioners
  - Schedulers
  - Active Queue Management
- QoS metrics
  - Delay (OWD)
  - Jitter (IPDV)
  - Loss rate
  - Throughput
  - Bandwidth sharing with and without congestion
  - Flow protection
- Variable characteristics (test conditions)
  - Mechanism parameters

- Interaction of mechanisms
- Transport protocol mix (TCP/UDP)
- RTTs
- Number of flows
- Aggregation

5.3 Testbed

ENST Bretagne's local testbed is based on FreeBSD stations with Kame's IPv6 stack + the ALT-Q queuing framework. RENATER provides access to the 6NET backbone. Several test layouts can be set up, including LAN and WAN segments with several institutions.

5.3.1 Tests for AF-based services

Context and motivation

There have been discussions on the use of AF, the Diffserv's Assured Forwarding PHB, as the basic building block for certain network services and applications. The proposed services deal generally with rate assurance for in-profile traffic. More recently, lower delay services have also been associated to AF capabilities.

At the application level, data semantics can be mapped to AF classes and drop priorities to enhance performance. This way, even under the same congestion level, an AF network coupled with an AF-aware application (like MPEG video) can yield a better perceptual quality than Best Effort.

With this context in mind, RENATER/ENST Bretagne propose an initial test suite for AF based services, focused on the evaluation of bandwidth sharing fairness. Tests are grouped in three phases. The first two deal with the parameter tuning of the AF mechanisms, while the third deals with aggregation issues.

Further phases can be defined in order to evaluate other performance metrics and traffic scenarios.

Phase 1: Tuning of the core router

Objective: Tune a multi-level AQM mechanism (WRED) in core routers to achieve a behaviour compliant with the AF PHB. The settings should protect high priority packets, keeping throughput as high (and delay as low) as possible.

Specification overview: This phase can be realized by sending marked UDP flows at rates higher than the link's capacity, then measure loss rates and throughput per colour. The marking strategy should change from one run to the next, so that different mixes of packet priorities are tested.

Phase 2: Tuning of the edge router

Objective: Find the values of the conditioner's parameters that yield the best sharing of bandwidth for TCP flows. This means that if two flows enter a single AF class, the one with a higher profile (assured rate), should get a higher bandwidth. The values should also guarantee protection for TCP flows in presence of non-responsive UDP flows.

Specification overview: Send several TCP flows with different assured rates through an AF enabled router. Conditioner parameters are varied to evaluate their effect on bandwidth sharing. Protection can be tested sending UDP flows marked with the lowest priority.

Phase 3: Evaluation of fairness under aggregation

Objective: Verify the effect that RTT and number of flows has on bandwidth sharing under aggregation. Diffserv is designed for aggregates, but aggregates are made of individual flows with different RTTs. Therefore, even if fairness is observed at the aggregate level, individual flows might not show this fairness.

Specification overview: generate individually marked flows with different RTTs, aggregate them, mark the aggregates and send through a WRED router. Measure throughput at exit for individual flows and aggregates. Compare throughput for colour-blind and colour-aware marking at the aggregation point (Fig. 1).

Note: The generation of heterogeneous RTTs can be emulated with Dummynet. Edge routing tasks can be accomplished by the ALT-Q. Both tools are available for FreeBSD routers.

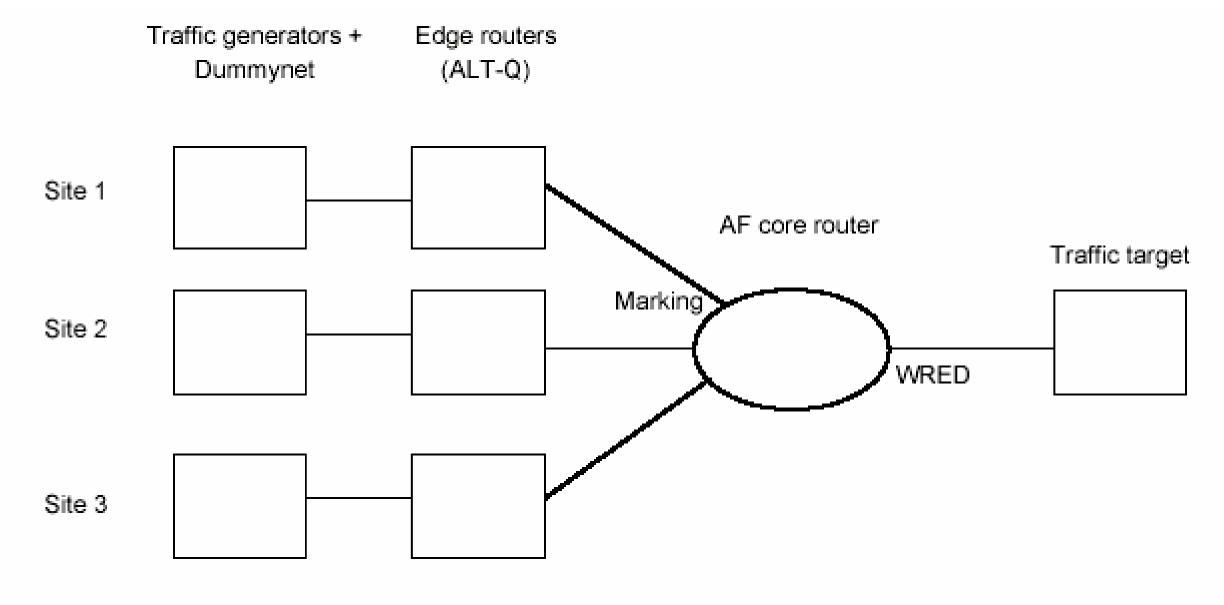

Figure 10 Evaluating Fairness of Aggregated Flows

6 Lancaster University

Lancaster University has conducted research into Internet Quality of Service (QoS) for many years. This includes QoS issues specific to IPv6 as well as IPv4. Until recently, this research has tended to concentrate on QoS issues in fixed networks (both access and core) and middleware in fixed hosts. However, we are now pursuing the more challenging picture of Internet QoS provisioning and management for mobile hosts and networks.

6.1 Experience with IPv6 QoS

Lancaster University has considerable experience in IPv6-related QoS issues. We were the first to specify extensions to RSVP to enable IPv6 flow label support [16]. To realise the use of IPv6 flow labels with RSVP, appropriate modifications were made to the ISI RSVP implementation. This was demonstrated over an IPv6 network in the Eurescom P702 project [13] using Lancaster University's IPv6 video server and client applications.

As part of the EU PETERPAN project [14], Lancaster University made a comparison of IPv4 and IPv6 for the support of GS (Guaranteed Service) and CLS (Controlled Load Service) RSVP flows over a hybrid IP-ATM QoS infrastructure [15].

6.2 Mobile IPv6 QoS Plans

The Mobile IPv6 protocol is not conducive to existing QoS paradigms. A mobile node (MN) can change its point of attachment in the Internet at any time during a communication exchange between QoS-sensitive applications. Thus, parts of (or in the worst case, all of) the intermediate network domains that the QoS traffic traverses may change over time. It is not difficult to see that any end-to-end QoS guarantees in place at the beginning of an application session can easily be broken when a MN moves location.

When a MN moves location, it has a significant effect on the QoS parameters of real-time applications. The handoff process itself (the MN moving from one media to another) may introduce significant packet delay and/or packet loss depending on the latency of the handoff process. Additionally, the new network location of the MN may not be able to deliver the bandwidth needed by the QoS sensitive applications, thus throughput will be reduced. Even if throughput is not reduced, end-to-end packet delay may be increased due to a new, larger end-to-end path. This is especially so if triangular routing is employed at any time during the application session. Furthermore, the new network could be operated by a different network provider; hence, the MN may not have the appropriate service agreement with the provider for the desired QoS to be delivered by the new network.

In the Intserv/RSVP QoS paradigm, resources for the application session in question are reserved on intermediate nodes via explicit signalling from the participating end hosts. When a MN (which could be a sender and/or receiver) changes its location, this signalling must be propagated on the 'new' intermediate parts of the network and attempt to preserve the required QoS. Since RSVP is not able to cater for such a mobile scenario, RSVP modifications/extensions or new QoS signalling protocols must be developed. Recent proposals for these include [17], [18], [19], [20], and [21].

Lancaster University will analyse existing proposals for QoS provision in MIPv6 and provide improvements/amendments where appropriate.

In a similar fashion, the Diffserv paradigm was not designed to cater for mobile environments and modifications/extensions to the Diffserv model or new protocols are needed. Lancaster University will be concentrating mostly on the provision of Intserv/RSVP in a MIPv6 environment rather than Diffserv. However, findings from other research efforts into Diffserv and MIPv6 (e.g. MOBYDICK [22]) will be incorporated where appropriate.

To summarise, there are several issues related to QoS in MIPv6 that Lancaster University will investigate:

- Handoff latency
    - need to minimise packet loss/delay during the handoff process
- Roaming between heterogeneous media/networks
    - need to cope with changes in available bandwidth
    - possible changes in packet delay due to changes in end-to-end path
- Roaming between different service providers
    - possibly major changes in end-to-end path
    - lack of roaming service agreements
- Adaptive QoS protocols
    - analysis of Intserv/RSVP capabilities for MIPv6
- Multihomed/Multi-interfaced mobile nodes
    - need a management mechanism interfacing with QoS protocols.

Note there will be some overlap between the above issues and activities in A4.1 (handoff latency analysis) and A4.5 (host multihoming solutions)

6.3 Mobile IPv6 QoS Testbed

Figure 11 shows a possible configuration of the MIPv6 QoS testbed at Lancaster. Heterogeneous access networks comprise:

- 802.11a
- 802.11b
- GSM/GPRS
- Fast Ethernet
- Gigabit Ethernet

These heterogeneous networks give ample opportunity to test changes in available bandwidth as a MN roams between access types. In conjunction with activity A4.1, methods of improving the efficiency of the handoff process in order to minimise packet loss and delay will be evaluated. The testbed will also be configured to reflect possible changes in end-to-end path lengths during roaming. The use of an external service provider (Orange) will provide valuable experience when there are conflicts between the service contract in place and requested QoS by the applications.

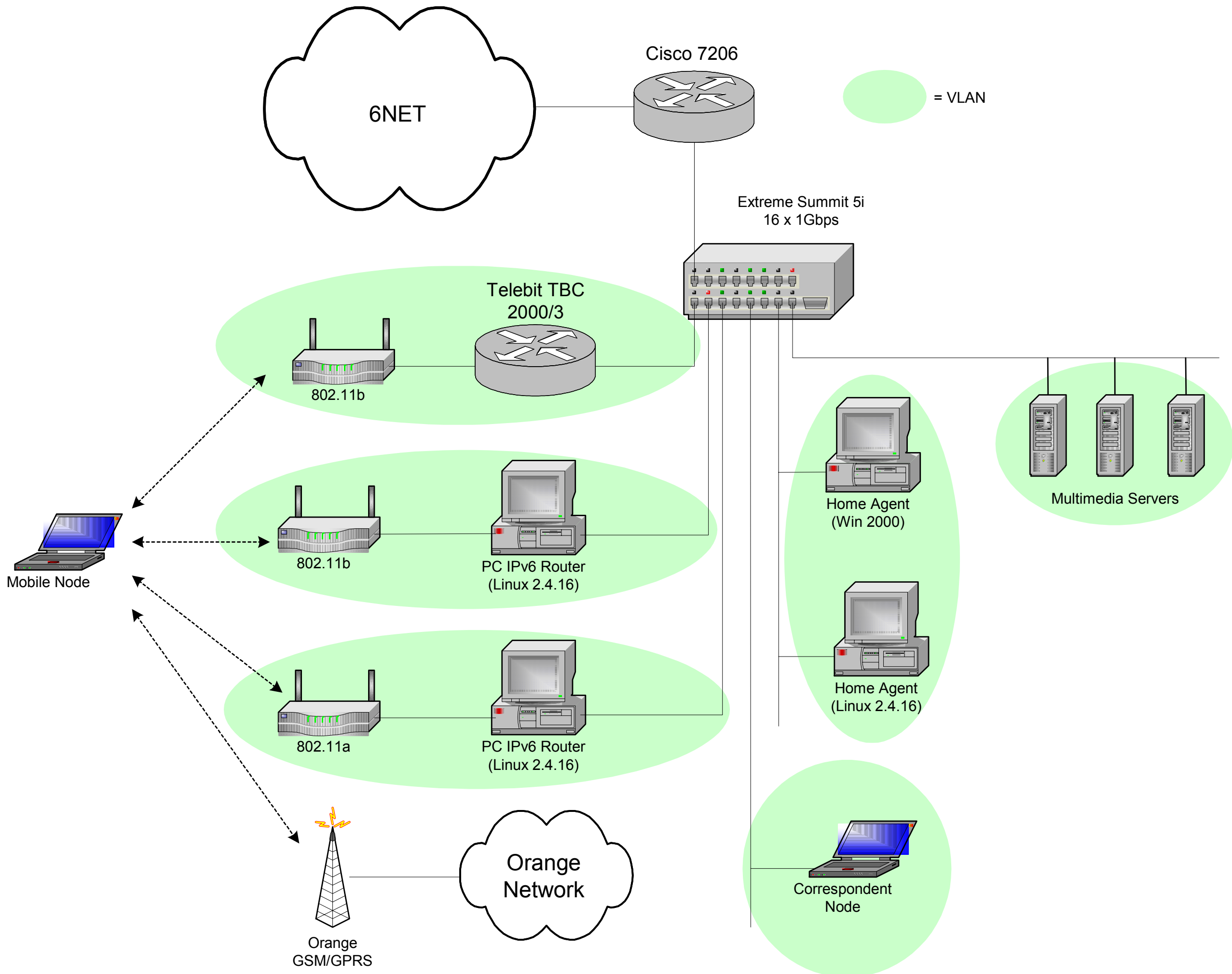

Figure 11 ULANC Mobile IPv6 QoS Testbed

Intermediate routers will be RSVP enabled and open source RSVP implementations will be modified with appropriate mobility extensions.

The multimedia servers are able to stream a variety of data including MPEG-1, MPEG-2, and mp3 audio. Traffic measurement utilities such as Netperf and MGEN will also be used to more accurately analyse packet delays, packet losses and throughput.

7 Cisco IOS IPv6 QoS Support

IPv6 QoS is officially supported since Cisco IOS 12.2(13)T. Documentation is available at [25].

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