An Experimental Network Infrastructure Supporting QoS

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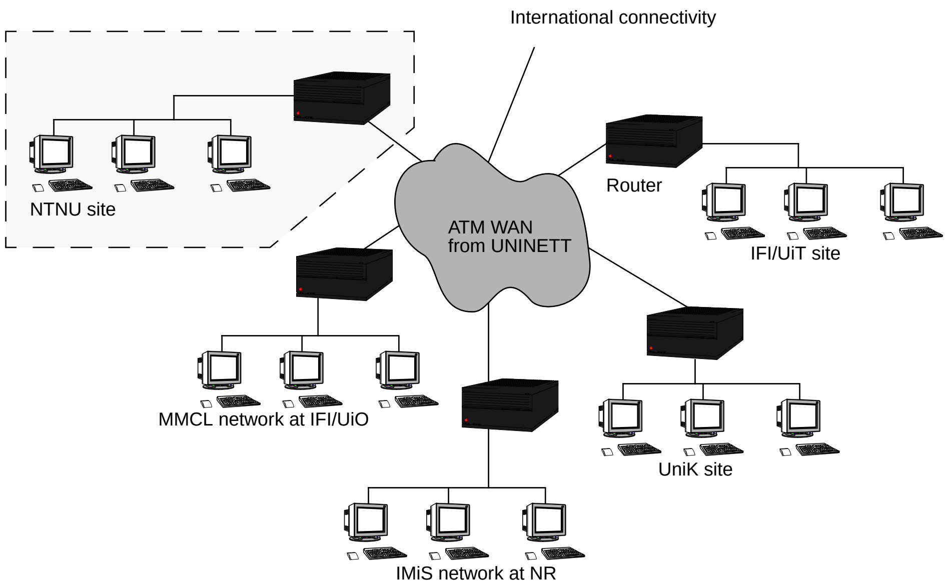
NOTAT / NOTE



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Lars Aarhus
Jannicke Riisnæs
Tore Solvar Karlsen

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Lars Aarhus, Jannicke Riisnæs, Tore Solvar Karlsen

Sammendrag/Abstract:

This document describes the experimental network infrastructure under development as part of the ENNCE WP1 project. The infrastructure intends to offer a high capacity networking environment for doing research on distributed multimedia applications. Important network characteristics include support for IPv6 and Quality of Service.

Early experiences with QoS in the network based on an RSVP experiment are also discussed.

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Norsk Regnesentral/Norwegian Computing Center
Gaustadalléen 23, Postboks 114 Blindern, N-0314 Oslo, Norway
Telefon (+47) 22 85 25 00, telefax (+47) 22 69 76 60

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Lars Aarhus
Jannicke Riisnæs
Tore Solvar Karlsen

Norsk Regnesentral
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1 Introduction

This document describes the experimental network infrastructure under development at Norwegian Computing Center (NR), Department of Informatics at University of Oslo (Ifi/UiO), Center for Technology at Kjeller (UniK) and Department of Informatics at University of Tromsø (Ifi/UiT) for the ENNCE project. The Norwegian academic network for research and education, UNINETT, provide connections between the different institutions.

The infrastructure intends to offer a high capacity networking environment for doing research on distributed multimedia applications by partners in the ENNCE project according to the ENNCE project plan [1]. The environment is now established, but not yet finished at all institutions. This document focuses on the most complete part, the intermediate infrastructure in the Informatics building at Blindern. Some of the content is direct citations from the document “Experimental IPv6 Network in Norway” [3], and is repeated here as not every part of the infrastructure was in place at the time of that writing.

The rest of this introduction gives an overview of the network sites, and presents the relationship and cooperation between the ENNCE project and other projects in Norway occupied with similar network infrastructure establishment.

Section 2 contains a more thorough technical description of the experimental infrastructure, including network components, network topology, IPv4/IPv6 address structure and support for Quality of Service (QoS) in the network.

Section 3 discusses the experiences gained regarding QoS when utilizing the infrastructure in an experiment involving resource reservation and RSVP.

Finally, there is a short section presenting ideas for future work on the infrastructure.

1.1 Network sites

The network infrastructure described in this document comprises the institutions at NR, Ifi/UiO and UniK. Main focus is on the part of the infrastructure located in the Informatics building at Blindern, host to both NR and Ifi/UiO. The corresponding part at UniK is not yet fully operational, and therefore not as thoroughly described.

Ifi/UiT are part of the ENNCE W2 project, but not yet heavily involved in the establishment of the infrastructure presented here.

The separate infrastructure used by other partners in the ENNCE project e.g. Norwegian Defense Research Establishment (FFI) is not covered in this document.

The technical solution is based on distributed IPv4/IPv6 labs with ATM links between the institutions (wide area interconnection) and 100BaseTX Ethernet and Wireless LAN for local network access. The QoS support is provided through configurable ATM links, and resource reservation using RSVP at IP level.

1.2 Project cooperation

Building a wide area network infrastructure is expensive, and can not solely be accomplished within the framework of ENNCE. Cooperation between projects is therefore necessary in order to maximize funding resources. The ENNCE project shares similar requirements and has close relationship with the following projects:

- IMiS Kernel [13]; Infrastructure for Multimedia applications in Seamless networks at NR, whose focus is on achieving seamlessness on both user, application, equipment and network level
- MMCL [12]; MultiMedia Communication Laboratory at Ifi/UiO, whose focus is on distributed multimedia, mobility and Internet research
- UNINETT Forskningsnett [14] and Testnett [15]; national experimental infrastructure for academic and research institutions, which focuses on providing high capacity inter-connections for doing advanced multimedia and network research

The ENNCE project shares the same physical infrastructure as IMiS Kernel at NR, and as MMCL at Ifi/UiO. Furthermore, it is part of the national experimental infrastructure from UNINETT as indicated in Figure 1.

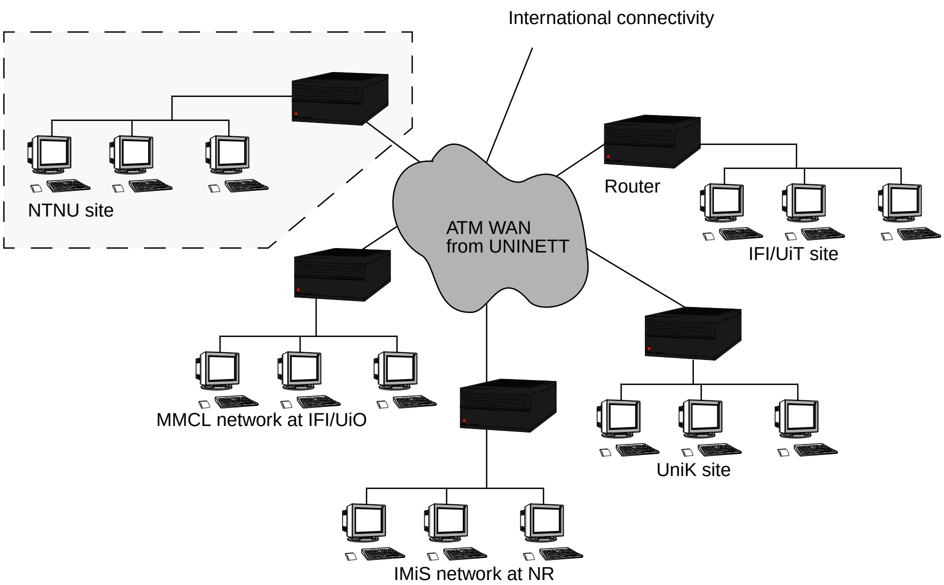

Figure 1 National experimental network infrastructure using ATM. NTNU is part of the infrastructure, but not an ENNCE project partner (shaded region).

The ENNCE network infrastructure is governed by two fundamental network design principles. The environment should provide:

- A *high capacity* network for demanding multimedia applications
- An infrastructure for testing purposes with the possibilities to introduce *instablities*. Such instabilities are not possible to introduce in a production network environment

These principles are in common with ongoing international activities such as the Internet 2 project [6] in the USA.

2 Network Infrastructure

This section presents the ENNCE network infrastructure in greater detail, with focus on the part located in the Informatics building at Blindern, host to NR and Ifi/UiO. The sites at UniK and Ifi/UiT have a similar structure, but are not described in this document, because work on the infrastructure has just started.

An overview of the NR and Ifi/UiO part of the ENNCE network infrastructure is given in Figure 2.

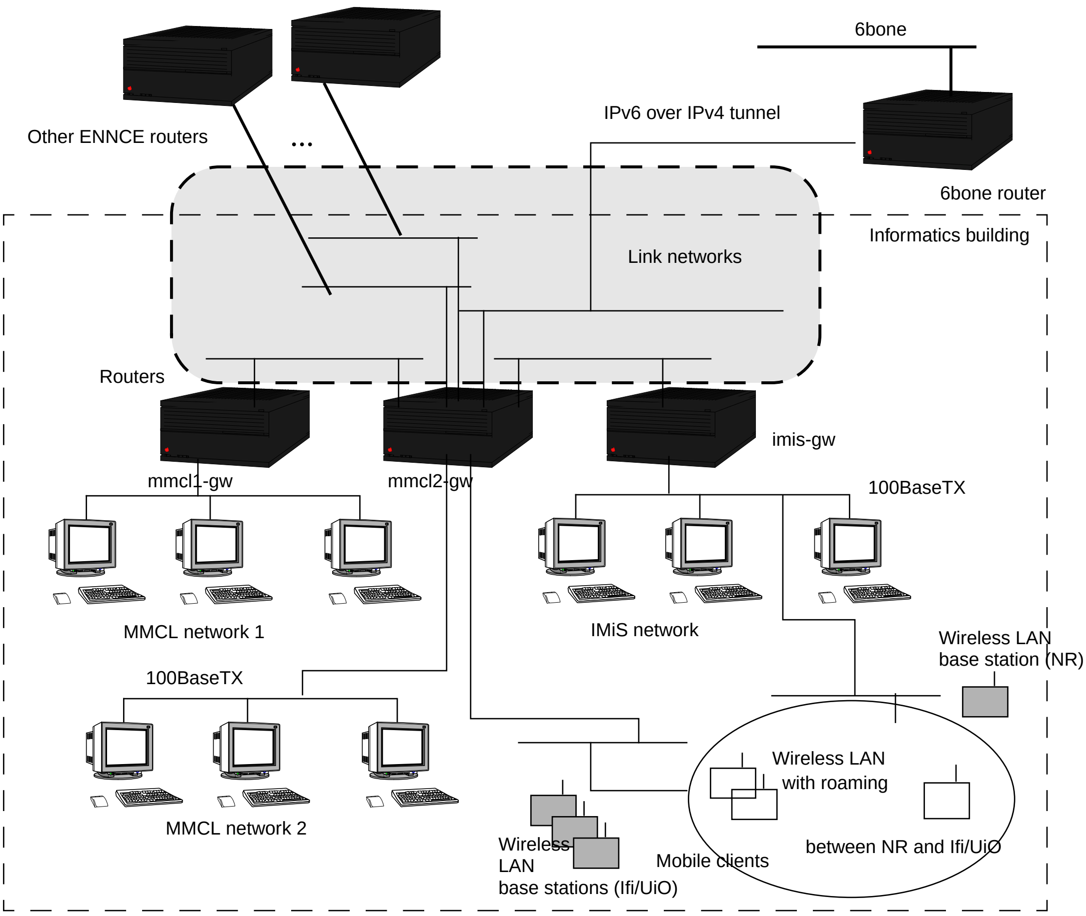

Figure 2 Intended ENNCE network infrastructure (NR, Ifi/UiO) at IP level. Link networks are realised through ATM technology (shaded region).

It should be noted that the infrastructure above is the *desired*, long term solution. The current topology is slightly different due to vendor hardware and software mismatch. In the remainder of the document, all descriptions relate to the current topology only.

The rest of this chapter is divided into four parts. First, the major network components are described, including some important requirements for inter-operation. Then, the network topology, both locally in the Informatics building, nationally between the other institutions, and internationally to other network infrastructures, are presented. Finally, the local IPv4 and IPv6 address plans are described, before the existing QoS support is discussed.

2.1 Components

Descriptions and general requirements for the major network components - router, ATM switch, name server, and hosts - are presented below.

IPv6 capable router

The chosen router must perform according to the following requirements:

- have the ability to run IPv6 and IPv4 software, according to the latest standard modifications, including tunneling
- have the ability to host ATM interfaces with traffic shaping
- have the ability to host two or more 100BaseTX ethernet interfaces
- have the ability to host ISDN interface cards

The Cisco [7] 7206 router was selected because of its capability to use advanced interface cards from the Cisco 7000 router family, at a lower entry cost than the other 7000 series routers. The router has six interface slots. Two slots are occupied by the advanced PA-A2 ATM-card with traffic shaping. A third slot is allocated to a Fast Ethernet interface. This leaves three empty slots for individual needs, such as additional Ethernet ports or ISDN.

ATM switch

NR and Ifi/UiO have jointly purchased a FORE 200WG ATM switch which is used to interconnect the ATM-capable routers and provide access to the UNINETT ATM infrastructure. ATM services can be located in both the Cisco routers and in the ATM switch. The ATM switch is intended to realise the link networks in Figure 2, thereby providing a QoS-controlable network infrastructure.

Name server

The main Ifi/UiO domain name server (DNS) is upgraded to handle AAAA records [17][1], which is necessary for serving IPv6 addresses. Ifi/UiO-local administrative tools (Machine Data Base, MDB) are currently being extended to handle IPv6 addresses. It is assumed that each site also operate its own name server. NR have configured a similar machine.

Reverse IPv6 address lookup is also implemented on both name servers.

IPv6 hosts

Currently available platforms with IPv6 (and IPv4) connectivity:

- Solaris 2.5/Ultrasparc 1 with SUNWipv6 package [8]
- Windows NT 4.0/x86 with Microsoft IPv6 support[9]
- FreeBSD 2.2.5/x86 with INRIA IPv6 software support[10]
- Linux 2.1.90/x86 with kernel IPv6 stack [11]

Specific configuration details regarding most of the network nodes are found in Table 3 and Table 4 in section 3.1

1. AAAA records are to be replaced by A6 records [22] in the near future.

2.2 Topology

Figure 3 below presents the current intermediate network topology. Due to a mismatch between vendor hardware support in the IPv6 software and the ATM interfaces in the routers, it was not possible to implement the intended design based on the local ATM switch from the beginning. Instead, an advanced temporary router without the mismatch was added to the infrastructure in order to achieve national IPv6 connectivity. The situation at UniK and Ifi/UiT is similar, with the current infrastructure being temporary, and the intended design not yet implemented.

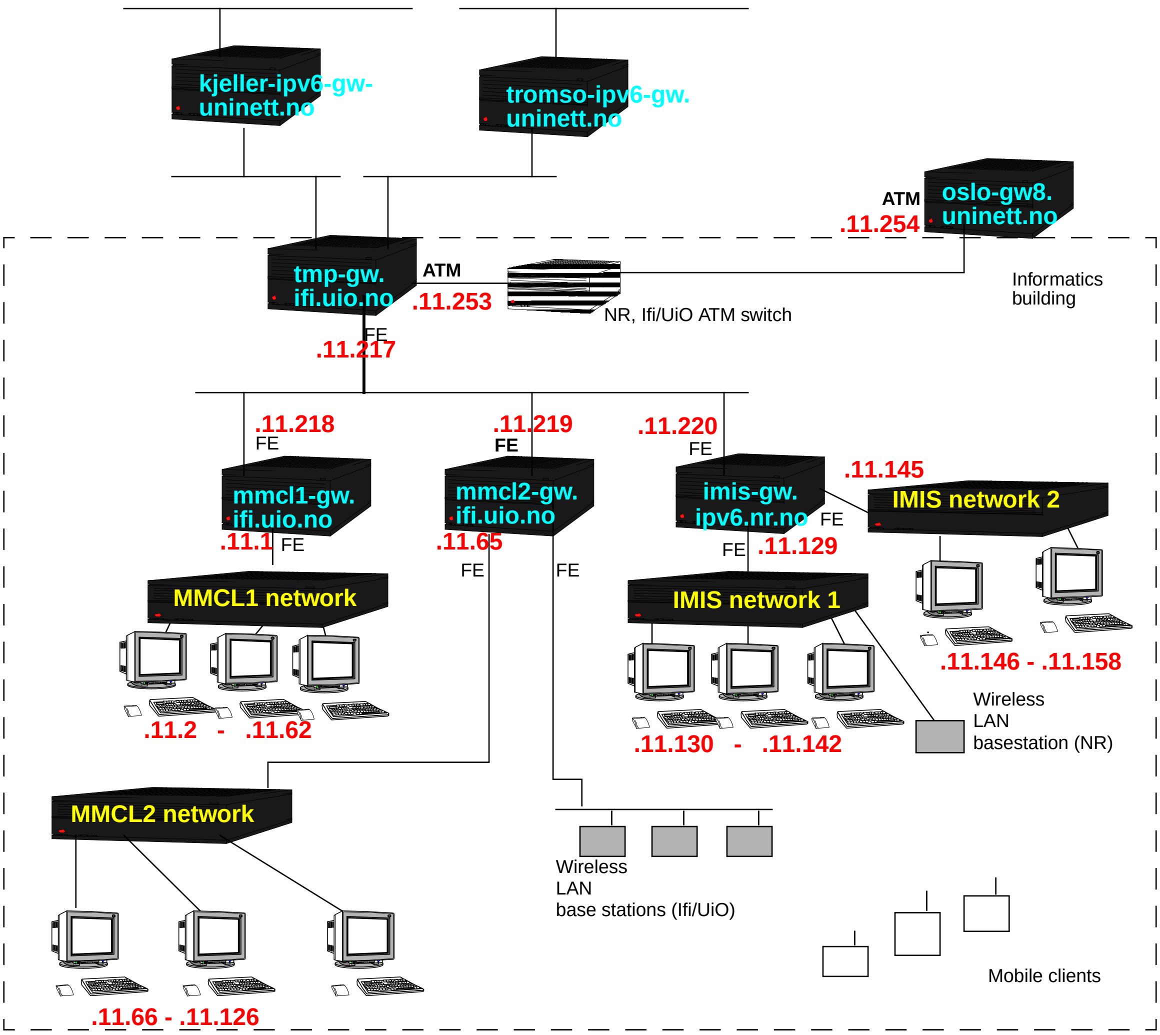

Figure 3 Current intermediate network topology at IP level

Wide area connection within UNINETT is accomplished using ATM. ATM is chosen since this is the current high speed wide area network infrastructure available at the institutions, and since it has the ability to dynamically set up channels with QoS requirements and negotiate QoS parameters during the lifetime of a connection.

In the short term UNINETT will supply 2Mbits ATM SVC connectivity between the different sites, as none of the institutions/projects have yet explicitly quantified their bandwidth needs. This is expected to change as more experiments on UNINETT Forskningsnett and Testnett are conducted, and traffic demands of the multimedia applications are known.

International connectivity to the experimental IPv6 international backbone 6bone [5] is achieved through IPv6 over IPv4 tunnelling. Later, this will possibly be obtained with dedicated ATM circuits to an international 6bone router.

Connectivity to Nordunet2, Internet2 and European network providers is intended. Access to the Internet 2 project will be possible through UNINETT, provided that relevant projects and experiments can be established with co-operating research and academic institutions in the USA.

2.3 Address structure

IPv6 [20] is a new version of the Internet Protocol with expanded addressing capabilities, and support for address autoconfiguration. The protocol also provides flow-based QoS labelling, and has built-in support for IP mobility and security. A good introductory book on IPv6 is given in [4].

Introducing IPv6 as a new protocol will be done gradually, mainly by introducing upgrades and new versions of existing operating systems with a dual IP stack, including both IPv4 and IPv6. The decision whether to use the IPv4 protocol, or the IPv6 protocol in communication between hosts, is done using DNS. In the future IPv6 will be the preferred protocol, but there will be many IPv4-only hosts in the Internet demanding IPv4 communication for several years. Thus, all nodes in the ENNCE experimental network infrastructure will be configured with both IPv4 and IPv6 support.

This means that each interface in the experimental network must have at least one IPv4 address.

IPv4 address plan

The NR and Ifi/UiO part of the infrastructure has been allocated a test IPv4 network from UNINETT (`128.39.11.0/24`). This network is divided into several smaller networks providing the addresses needed for Ifi/UiO, NR and the link networks between the different sites according to Table 1.

Table 1: IPv4 address plan, 128.39.11.0/24 (networks not yet operational are in italics)

Nodes	Block	Network	Number of addresses	Comments
0-63	26	MMCL1	64	Primary MMCL network (stable)
64-127	26	MMCL2	64	Secondary MMCL network (experimental) with mobile clients
128-191	26	IMiS	64	IMiS Kernel network 1 and 2
192-195	30	MMCL1-TFoU	4	Link network to Telenor FoU
196-199	*30*	*?*	*4*	*Not allocated*
200-207	29	MMCL1 - SCI	8	Link network to SCI-cluster
208-215	*29*	*?*	*8*	*Not allocated*
216-223	29	Router network	8	Temporary router network tying together mmcl1-gw, mmcl2-gw, imis-gw and tmp-gw
224-227	*30*	*MMCL1-NTNU*	*4*	*Link network*
228-231	*30*	*MMCL1-UiB*	*4*	*Link network*
232-235	*30*	*MMCL1-Ifi/UiT*	*4*	*Link network*
236-239	*30*	*MMCL1-TFoU*	*4*	*Link network*
240-243	*30*	*MMCL1-UniK*	*4*	*Link network*

Table 1: IPv4 address plan, 128.39.11.0/24 (networks not yet operational are in italics)

Nodes	Block	Network	Number of addresses	Comments
244-247	*30*	*MMCL1-IMiS*	*4*	*Link network*
248-251	*30*	*MMCL1-MMCL2*	*4*	*Link network*
252-255	30	MMCL1-UNINETT	4	Link network to UNINETT

IPv6 address plan

The administration of the IPv6 address space is still not standardized. IETF has taken the initiative to establish a wide area experimental IPv6 network infrastructure, 6bone. That project is allocated the `3ffe::/16` network. To achieve 6bone connectivity, it is necessary to use unique 6bone addresses. Currently, Norway is allocated the `3ffe:2a00::/24` network segment, which is supposed to cover the need of all Norwegian ISPs.

According to [18], IPv6 unicast addresses are aggregatable with contiguous bit-wise masks similar to the IPv4 addresses under Class-less Interdomain Routing [16]. There are several forms of unicast addresses in IPv6. These are:

- the aggregatable global unicast address
- the unspecified address
- the loopback address
- the IPv4-capable host address
- the site-local address
- the link-local address
- the NSAP address
- the IPX hierarchical address

Each IPv6 address is a 128 bits number. The address is divided in a network part and a host part. The prefix number shows the length of the network part of the address. For hosts, the last 64 bits are derived from the Ethernet address [21].

The national IPv6 experimental network is sub-divided into ISP networks and ISP subnetworks. The proposed address structure presented in Table 2, is a slight modification of the address plan in [19] since the structure supports a higher number of ISPs.

Table 2: IPv6 address plan, 3ffe:2a00::/24

Top Level Aggregation Identifier (TLA)	Pseudo TLA (pTLA)	Next Level Aggregation (NLA)	Network and site level aggregation		64 bits interface ID	
6bone	Norway	**ISP**	Network	Subnetwork	Host	Structural location
3ffe	2a	0001	001	001	-	6bone:No:Uninett:UiO:MMCL1
3ffe	2a	0001	001	002	-	6bone:No:Uninett:UiO:MMCL2
3ffe	2a	0001	002	001	-	6bone:No:Uninett:NR:IMIS1
3ffe	2a	0001	002	002	-	6bone:No:Uninett:NR:IMIS2
3ffe	2a	0001	003	-	-	6bone:No:Uninett:UiT

Table 2: IPv6 address plan, 3ffe:2a00::/24

Top Level Aggregation Identifier (TLA)	Pseudo TLA (pTLA)	Next Level Aggregation (NLA)	Network and site	level aggregation	64 bits interface ID	
3ffe	2a	0001	004	-	-	6bone:No:Uninett:UniK
3ffe	2a	0001	fff	001	-	6bone:No:Uninett:Link:NR
3ffe	2a	0001	fff	003	-	6bone:No:Uninett:Link:UniK
3ffe	2a	0001	fff	004	-	6bone:No:Uninett:Link:UiT
3ffe	2a	0001	fff	007	-	6bone:No:Uninett:Link:UNINETT

An example IPv6 address from this structure is the IPv6-capable router at NR, whose IMiS1 IPv6 address is `3FFE:2A00:0100:2001::1`.

2.4 QoS support

At the moment QoS support is partly provided by configurable ATM links between the institutions, and partly by resource reservation using RSVP locally in the Informatics building. Later, resource reservation may also be extended across the ATM links, provided RSVP software is installed at each next hop router.

As the infrastructure continues to serve as an experimental testbed, other types of QoS support is expected to become important too. This includes differentiated service architecture for scalable traffic classification without the need for per-flow state, and QoS mechanisms developed within the ENNCE project, e.g. DaCaPo [2]. The QoS negotiation mechanisms suggested in ENNCE WP1 [29] will be evaluated on this infrastructure using the applications chosen for this context (c.f. [30]). The QoS support in the hardware for these applications need to be in place for conducting these experiments.

3 QoS Experiences

The content of this section is completely based on the document “Early Experiences with Resource Reservation” [23] .

As part of the IMiS/ENNCE project, an experiment was set up to gain valuable QoS experience. The goal of the experiment was to evaluate networked QoS support, and demonstrate the effect of resource reservation in a congested network. This section describes the experiences and results.

The idea of the experiment was to configure a network system with at least one host on either side of one or two routers, use a traffic generator, Mgen [24], to generate different combinations of 1 Mbps reserved and unreserved UDP flows between the end hosts until network congestion occurred, and measure the effect (throughput) on the reserved flow(s).

3.1 Different network infrastructure attempts

The original intention was to use the ENNCE network infrastructure in Figure 2. However, as it was discovered that there was no current support for the ATM interface card (PA-A2) in the IPv6 software (experimental IOS) for the Cisco 7206 router, this was not possible. Instead, it was decided to add an advanced temporary router, and use the intermediate 100BaseTX Ethernet network infrastructure at NR and Ifi/UiO in Figure 3 for the experiment.

RSVP (ReSerVation Protocol) [25] was chosen as the QoS signalling protocol. However, new problems were discovered when trying to deploy RSVP in the IMiS network nodes. Most importantly, the IPv6 router software had no support for RSVP signalling either (even though the commands were legal!). Additionally, it was strongly recommended that the RSVP host daemon (SolarisRSVP.0.5.0 [26]) on Solaris 2.5 should have all OS patches installed, which conflicted with the non-patched OS requirements in the IPv6 software (SUNWipv6 package). Installing the IPv6 software on a patched kernel was never really tested, though. There were no problems installing the RSVP host daemon (ISI rel4.2a4 [27]) on FreeBSD 2.2.5 with IPv6 support (INRIA). A description of all the IMiS network nodes is in Table 3.

Name	Operating System	Hardware Type	IPv4 Address
varda	SunOS 5.5	Sun Sparc Ultra	128.39.11.130
tulkas	FreeBSD 2.2.5	PC, i486	128.39.11.131
ulmo	Windows NT 4.0	PC, i486	128.39.11.132
manve	SunOS 5.5	Sun Sparc Classic	128.39.11.146
nienna	FreeBSD 2.2.5	PC, i586	128.39.11.147
imis-gw	IOS 11.3/ experimental IOS	Cisco 7206	FE0/0: 128.39.11.129 FE3/0: 128.39.11.145 FE4/0: 128.39.11.220

Table 3: Description of the nodes in the IMiS network

In order to do any resource reservation experimenting at all, it was decided to re-install the IPv4 router software with RSVP support (IOS 11.3) in the IMiS network, and perform the experiment on the IPv4-only network infrastructure in Figure 4.

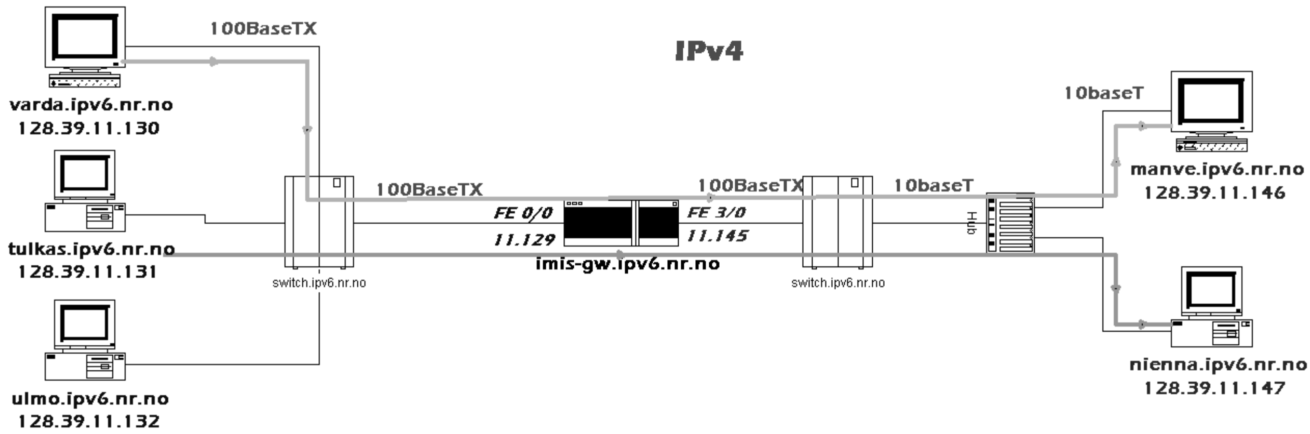

Figure 4   The IMiS network for testing QoS with RSVP.

In this system configuration RSVP signalling (PATH and RESV messages) between hosts and router was successful, and RSVP state was properly maintained on the router. However, because of the configuration, limiting the downstream traffic in the router was impossible, as during congestion packets were naturally dropped in the switch, and not in the router. A possible solution would have been to replace the downstream 100BaseTX Ethernet card with a 10BaseT Ethernet card, but this was unavailable for the project.

Instead, it was decided to insert another router (Cisco 2503) in the network, and limit the traffic by solely using the asynchronous serial line (with maximum throughput 39 kbps) for communication between the two routers. The resulting network infrastructure is in Figure 5.

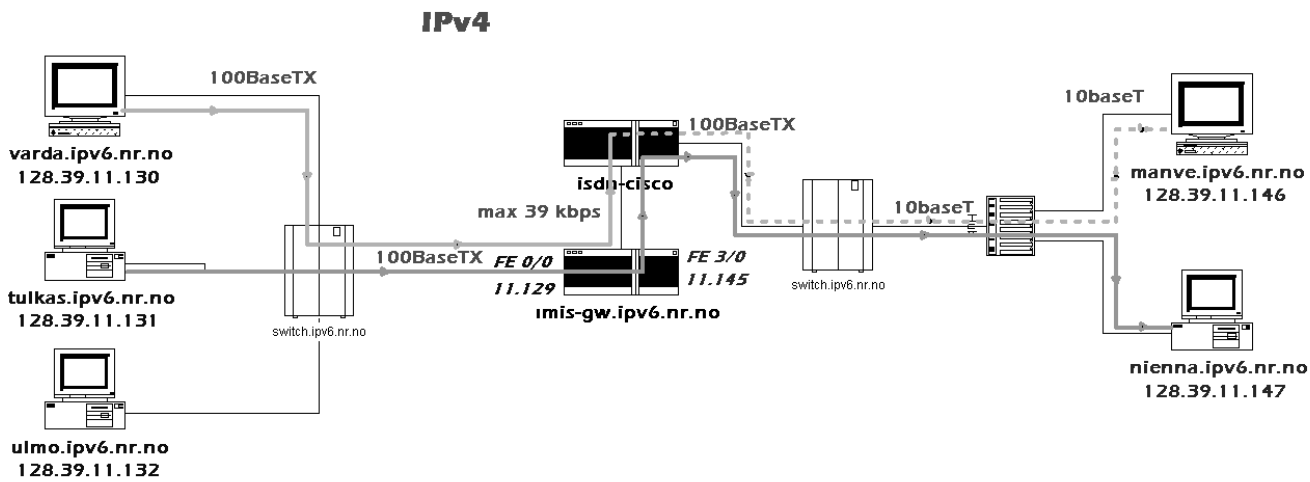

Figure 5   The IMiS network with two routers to limit the traffic.

Once again, in this system configuration RSVP signalling was successful, and RSVP state properly maintained. However, because there was no RSVP support in the new router, the end-to-end QoS principle did not apply, as only downstream (one-way) traffic reservation was possible. Also, the slow serial line meant that one of the Solaris hosts (manve) would time out during booting, and fail to restart properly. Additionally, a similar RSVP experiment using a serial line had already been completed in Norway [28], therefore this IMiS/ENNCE experiment should preferably focus on something different, like using ATM as the core technology.

Although none of the above objections would prevent experiment accomplishment, it was decided to change the network infrastructure once more. Now that the IMiS network was IPv4-only, support for the ATM interface card in the router existed, and the originally intended ENNCE network infrastructure over ATM was again possible. Thus, IPv4 router software with RSVP support (IOS 11.3) was re-installed in the MMCL network, too. A 2 Mbps permanent virtual connection (PVC) was established between NR and Ifi/UiO, and the RSVP host daemon (ISI rel4.2a4) was installed on FreeBSD 2.2.6 at Ifi/UiO. The resulting infrastructure is in Figure 6, while a description of the MMCL2 network nodes is in Table 4.

Name	Operating System	Hardware Type	IPv4 Address
fixus	FreeBSD 2.2.6	PC, i586	128.39.11.67
mmcl2-gw	IOS 11.3/ experimental IOS	Cisco 7206	FE0/0: 128.39.11.219 FE4/0: 128.39.11.65

Table 4: Description of the nodes in the MMCL 2 network

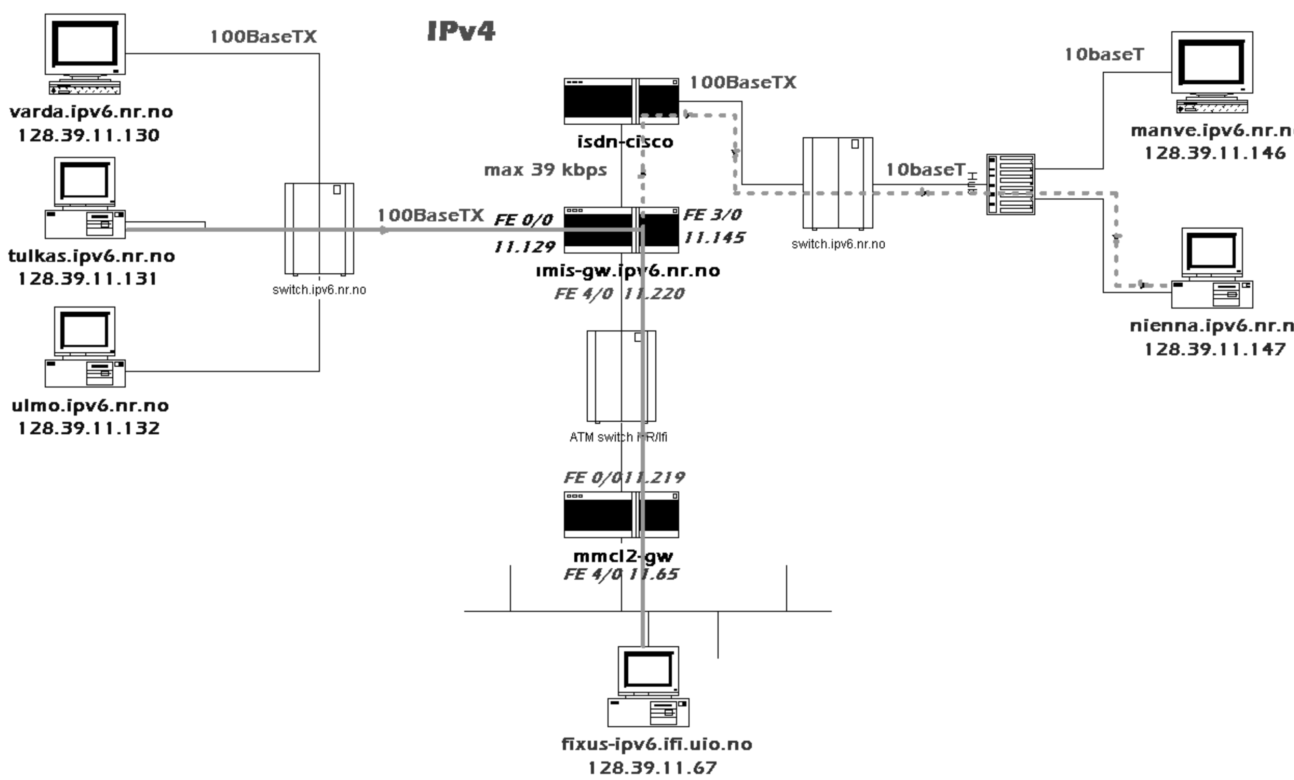

Figure 6 Test network infrastructure including both the IMiS and MMCL networks.

After increasing the hold queue to 200 packets on each ATM interface, also in this system configuration RSVP signalling between hosts and routers was successful, and RSVP state properly maintained in both routers. However, as it was discovered that there was no traffic control support (e.g. Weighted Fair Queuing) for the ATM interface card in the router software, no admission control and packet differentiation could be performed. This meant that the effect of resource reservation could not be demonstrated, as more than just RSVP signalling is necessary for QoS guarantees to be made in the network, which is illustrated in the throughput measurements in Figure 7.

A	Flow Size (appr in Mbps)	Reservation	Throughput (in Kbps)
Flow 1	1	No	583
Flow 2	1	No	581
Flow 3	1	No	596

Table E: Throughput measurements with no reservations on any flows (packet size 14oo bytes, duration 120 seconds)

B	Flow Size (appr. in Mbps)	Reservation	Throughput (in Kbps)
Flow 1	1	No	588
Flow 2	1	Yes	583
Flow 3	1	No	588

Table F: Throughput measurements with rsvp reservation on flow 2 (packet size 1400 bytes, duration 120 seconds)

Figure 7 Measurements indicate no difference in the throughput distribution between the unreserved flows in Table E, and the flows (one of three reserved) in Table F.

Now, the intermediate 100BaseTX Ethernet network infrastructure is again the present configuration, with IPv6 router software re-installed, but without RSVP and ATM support in the routers, as shown in Figure 4 with IPv6 instead of IPv4.

The problem with the current network infrastructure:

- incompatible software (IPv6) and hardware (ATM) on the routers
- no support for simultaneous use of IPv6 and RSVP in routers and on some hosts
- too large datalinks (100BaseTX Ethernet) for network congestion to occur

3.2 Discussion

The goal of the the experiment was to evaluate networked QoS support, and demonstrate the effect of resource reservation in a congested network. Although, no successful resource reservation has been completed, valuable insight in QoS configuration has been gained, and correct RSVP signalling and state maintenance achieved. Some misassumptions have been made in the process, but many lessons about network system configuration and RSVP have also been learnt.

In hindsight, the choice of a relatively inexpensive router (Cisco 7206) has proved to be a bad one. If a more advanced product from the Cisco 7000 router family had been chosen, many of the incompatibility problems would probably have been avoided.

A short technological conclusion based on the current network infrastructure:

- IPv6+ATM = incompatible (the IPv6 router software (experimental IOS) does not support the ATM interface card (PA-A2))
- IPv6+RSVP = incompatible (the IPv6 router software (experimental IPS) does not support RSVP, and IPv6 and RSVP host software on Solaris 2.5 require different patched kernels)
- IPv4+ATM = compatible
- IPv4+RSVP = compatible
- ATM+RSVP = incompatible (the IPv4 router software (IOS 11.3) does not support traffic control for the ATM interface card (PA-A2))

In short, the technology platform in the ENNCE network is not yet mature for next generation QoS support, when that includes both IPv6, RSVP and ATM.

4 Future Work

The experimental network infrastructure is under continuous development. Future work on the infrastructure as part of the ENNCE WP1 project includes:

- Installing a new experimental version of the IPv6 router software (IOS 12.0) on all routers when available. That version will hopefully support both IPV6, ATM, and RSVP simultaneously.
- Realising the originally intended ENNCE network infrastructure as described in Figure 2, with the ATM switch as a core component.
- Completing a successful resource reservation using RSVP, which demonstrates the effect in a congested network.
- Experimenting with the differentiated services architecture for scalable traffic classification without the need for per-flow state.
- Providing native ATM connections between specific hosts on some sites.

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