Experimental IPv6 Network in Norway

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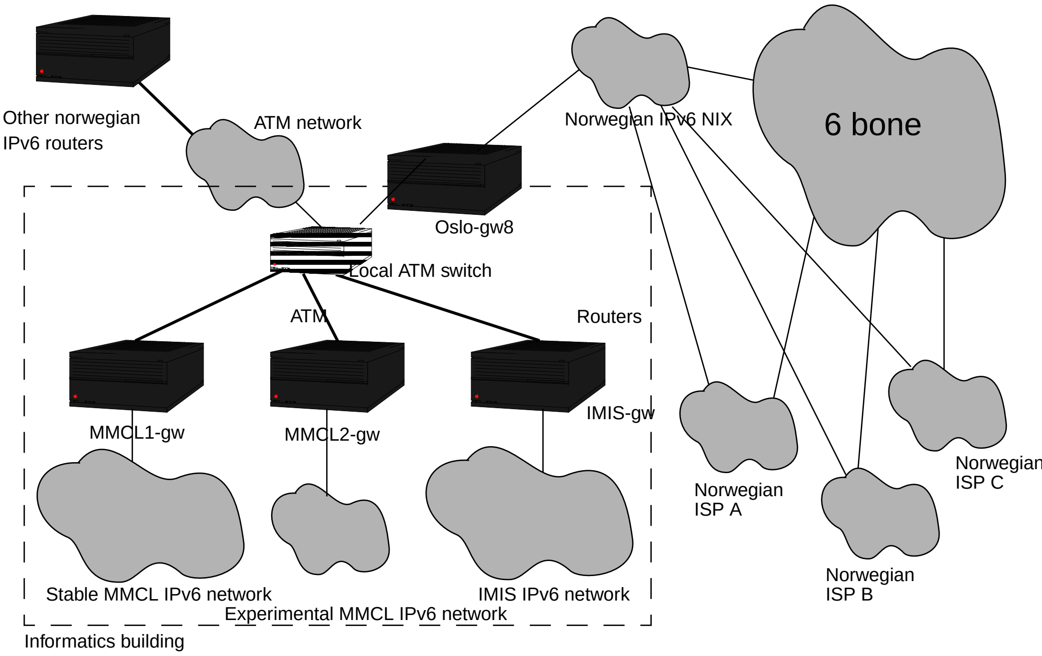

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Sammendrag/Abstract:

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The experimental network is financed by the Norwegian Research Council, Uninett A/S and University of Oslo(UiO) through the MultiMedia Communication Laboratory(MMCL).

Our intention with this document is to establish an overall plan about the first wide area, high capacity IPv6 network in Norway. This document describes a network infrastructure which is suitable both for the research- and eduational institutions and for the commercial ISP's. The network is designed to include similar planned IPv6 sites at UNIK (ENNCE WP2), NTNU (Plug&Play project), University of Tromsø (ENNCE WP2 project), Telenor Research and Development (Project I), and Ericsson A/S (IMIS Ericsson project) as they become available.

Our first step is to move our current IPv6 tunnel to an IPv6 capable router, and establish both IPv4 and IPv6 network connectivity between the laboratories located at Ifi/UiO and NR. Our next step is to establish IPv4 and IPv6 link networks to the planned IPv6 sites at our collaborating institutions. The third step is to establish a common national research network, IPv4 and IPv6 address plan, corresponding router configuration and use of Signalling Virtual Circuits (SVC) connections over wide area ATM connections between the trial sites. This step requires additional IPv4 address space, as well as SVC connectivity over ATM.

Both local and wide area network issues are disucssed in this report, and a first recommendation for IPv6 address space usage in Norway is included. Network infrastructure requirements for IPv6 network establishment is also included, and the configuration of our current network is given.

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1 Introduction

This document describes the IPv6[1],[2] experimental network with Quality of Service capabilities under development at Department of Informatics(Ifi) and Norwegian Computing Centre(NR) as part of the IMIS and ENNCE WP1 projects. The trial network is financed by the Norwegian Research Council, Uninett A/S and University of Oslo through the MultiMedia Communication Laboratory (MMCL). The network is designed to include similar planned IPv6 sites at UNIK (ENNCE WP2), NTNU (Plug&Play project), University of Tromsø (ENNCE WP2 project), Telenor Research and Development (Project I) and Ericsson A/S (IMIS Ericsson project) as they become available.

This document includes a short description of a nationwide IPv6 experimental network, available to all Internet Service Providers (ISPs). We focus on the part of the network which connects the research departments desribed above. These departments are already connected together using the ISP services from Uninett. The suggested solutions are according to Uninetts experimental network design.

Our intention is to establish the first wide area, high capacity IPv6 network in Norway within Uninett and to provide state of the art network infrastructure to be utilized in the IMIS and ENNCE projects as well as other research projects within NR, IFI and our collaborating institutions. The network is also intended as a carrier of multimedia content used for experimental research in the MMCL lab at IFI. ATM is chosen for Wide Area interconnection, while 100baseT, and Wireless LAN is used for local network access.

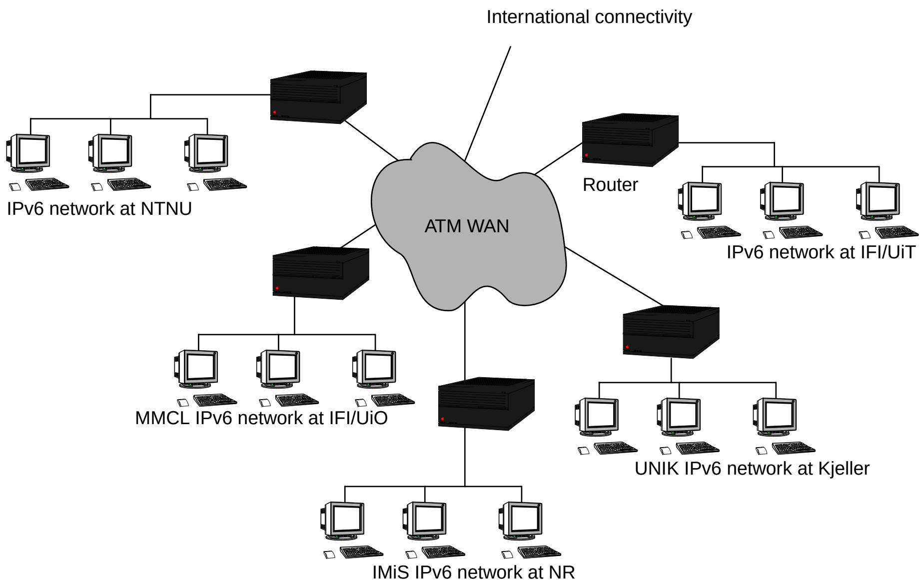

Figure 1 Using ATM WAN services to interconnect IPv6 sites

Figure 1 shows how ATM is used to interconnect routers with IPv6 capability to establish the national trial IPv6 network.

A trial node with an experimental IPv6 implementation for Linux has been operational since May 1997 at the University of Oslo, using IPv4 tunneling to the experimental IPv6 international backbone “6bone” [3] access node in Stockholm. Operation of this machine (**`la1ad.uio.no`**) by the radio amateur club [4] has been useful to gather experience for the trial network, but a more powerful infrastructure is required in order to support multimedia traffic and more complex network topologies.

Figure 2 shows the local IPv6 network infrastructure in the Informatics building where NR and IFI/UiO is located. Note that some of the workstations are connected both to the IPv6 capable router and directly to the ATM switch. This feature allows experiments with both pure ATM and IPv6 over ATM wide area interconnectivity. To support experiments with mobility, a wireless LAN is established in the building where mobile nodes can move seamlessly between the networks. Seamless access to other wireless networks in the experimental IPv6 network is planned.

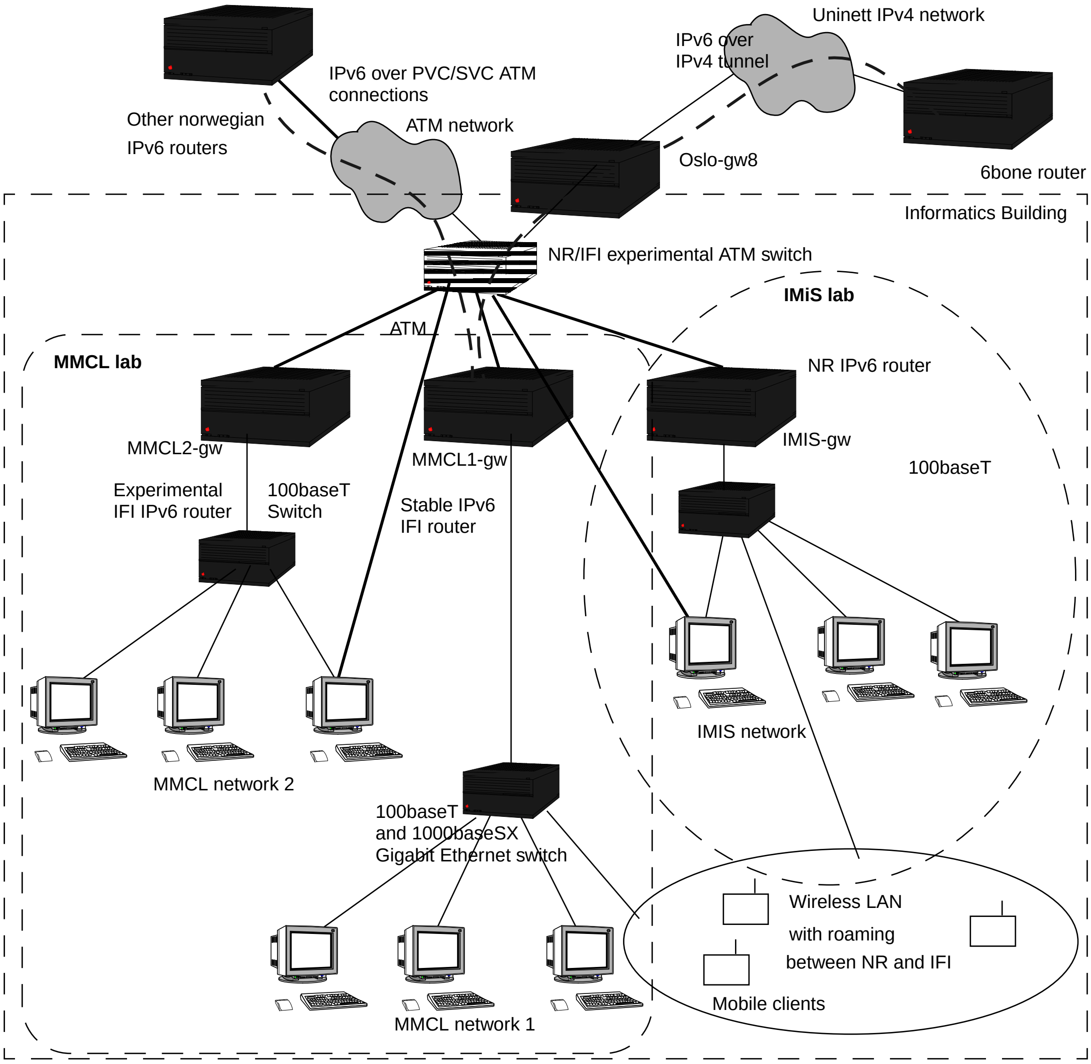

Figure 2   Local network infrastructure for the MMCL/IMiS laboratories

Figure 3 shows the IP networks built on the link-structure described in Figure 2 Note that the mmcl1-gw is designed as the stable router connecting all other IPv6 routers in the trial network. The mmcl1-gw also connects the trial network to 6bone through a IPv4 tunnel to the 6bone router.

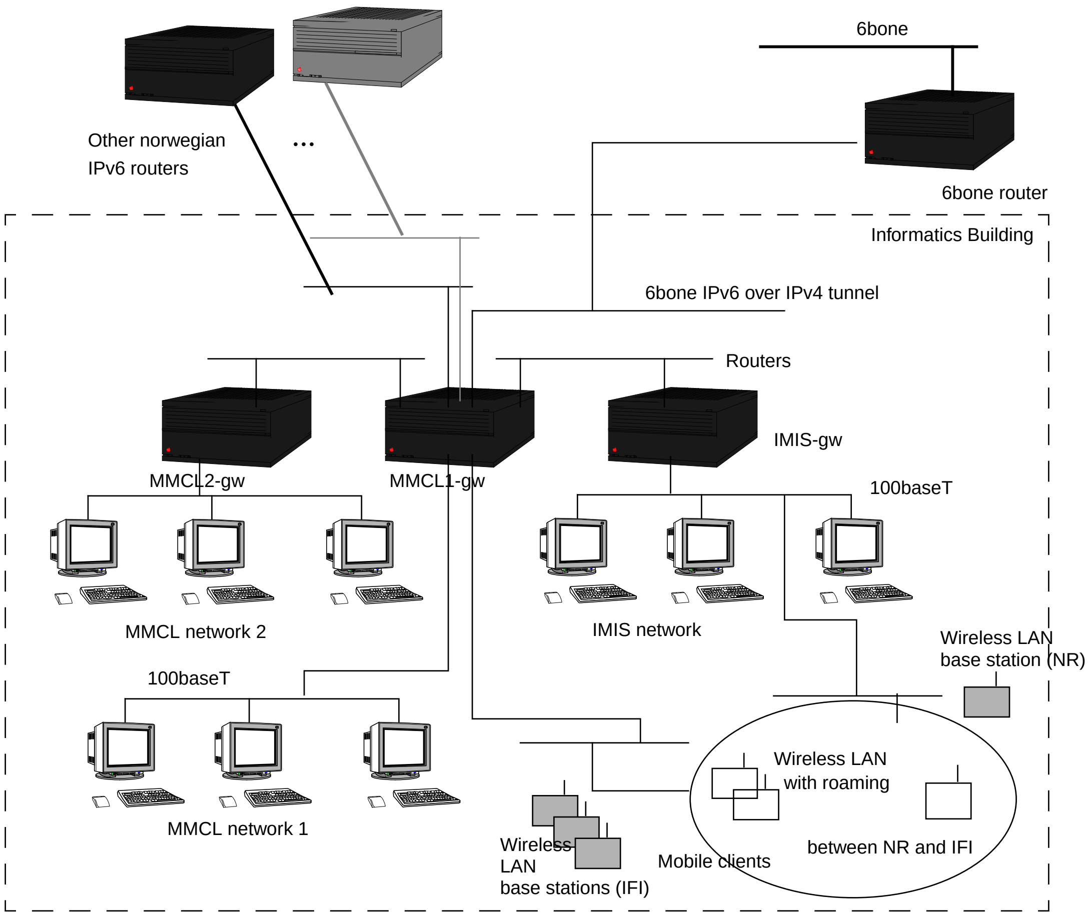

Figure 3 Local IPv6 network architecture (IP layer only)

2 Wide Area Interconnection

Wide area connection within Uninett will be 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.

The sites mentioned over are all already connected together through an IPv4 based network provided by Uninett. Between Oslo, Kjeller, Trondheim, Bergen and Tromsø the network is linked together by ATM connections. These connections are at the moment leased by Uninett from Telenor. Supernett [11] is a part of this ATM infrastructure.

2.1 Bandwidth requirements

None of the institutions/projects have explicitly quantified their bandwidth needs, and it may seem that this matter is less important than actual connectivity, combined with the possibility to experiment with dynamic bandwidth allocation.

On the short term Uninett will supply 2Mbits ATM SVC connectivity between the different sites. Long term solutions are still to be decided. In particular, we are interested in SDH links between the experimental networks. This solution would allow us to let the routers perform resource reservation with exact link capacities with very low bit error rates, since packets cannot be dropped as in the ATM network. Having SDH links would allow very interesting comparisons between ATM QoS reservation using for instance UNI 3.1 and router-based QoS reservation using SDH between the sites. Thus, we urge Uninett, to investigate opportunities for future SDH connectivity between the IPv6 trial sites.

2.2 International connectivity

International connectivity is initially obtained by tunneling to 6bone trough IPv4 and possibly later with dedicated ATM circuits to an international 6bone router. Connectivity to NORDUnet2, Internet2 and European network providers is intended. This is currently Uninett's responsibility and will be done in close cooperation with Uninett

3 Specification of Network Components

This section will describe the different network modules used to build the IPv6 network according to previous assumptions.

3.1 IPv6 capable router

The chosen router must perform according to the following requirements:

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

At this early stage of IPv6 development, we believe that the project benefits from a homogenous router environment since standardization is not yet fully completed. We decided to choose routers from Cisco[10] because:

1. Cisco is already used at all sites in the Experimental IPv6 network (Uninett, Telenor, NR, IFI, UNIK)
2. Cisco has an ongoing IPv6 development program, allowing selected customers to participate using early IPv6 beta releases trough the Cisco EMEA Technology program.
3. Cisco is heavily involved in the IETF standardisation work
4. Cisco has documented support for ATM with traffic shaping functionality required for the WAN aspects of the network.

IFI was accepted in the EMEA Technology program to establish the Multimedia Communication Lab and do initial IPv6 network planning. Cisco has also reserved advanced technical support to help us to get the network operational. IPv6 responsible at NR has also been included through the EMEA program at IFI since our infrastructure is colocated. If other IPv6 sites choose to use Cisco, they must establish a relationship with the Cisco EMEA Technology program as long as production versions of IOS with IPv6 support is not yet available.

3.1.1IPv4/IPv6 router: Cisco 7206:

The Cisco 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 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.

Table 1: Specification of Cisco IPv6 capable router

Product specification	Function
CISCO7206	Basic router chassis, including six interface slots
NPE200	Processor card, incl. 32MB RAM
C7200-I/O-FE-MII	Fast ethernet I/O controller
PA-A2-4E1XC-OC3SM	ATM interface with traffic shaping functionality
MEM-I/O-FLC16M	I/O PCMCIA Flash Memory, 20MB option
MEM-NPE-32MB	Cisco 7200 NPE 32 MB DRAM

Table 1: Specification of Cisco IPv6 capable router

Product specification	Function
PA-FE-TX	1-port Fast Ethernet 100BaseTx Port adapter
AT-MX300TX	Fast ethernet Transceiver 100Base-Tx RJ45/MII c
SF72C-11.2.9P	Cisco 7200 Serie IOS IP only Feature set
F-SM-MM-02	Transition SM/MM two-way converter

3.2 ATM infrastructure

NR and IFI has 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. For our local Classical IP over ATM [6] and Lan Emulation [7] networks, these services are located in the ATM switch, while PVC termination is done in the Cisco routers as IPv4 endpoints. However, seamless integration of IPv6 sites trough SVCs requires UNI3.1 signallig [12] configuration on both the routers and the involved ATM switches. This is intended as the experimental network is extended.

3.3 Nameservers

The main IFI nameserver is upgraded to handle AAAA records, and is currently serving IPv6 addresses. IFI-local administrative tools (Machine Data Base, MDB) are currently beeing extended to handle IPv6 addresses. It is assumed that each IPv6 site also operate their own nameserver, and NR has configured a similar machine.

Handling reverse name lookup is currently an open issue, and any feedback would be welcome to the authors of this document.

3.4 IPv6 client machines

We have currently established IPv6 connectivity on three platforms:

- Linux 2.1/x86 using the kernel IPv6 stack. This protocol stack has the advantage of source code availability and a fairly well documentet IPv6 API for initial IPv6 application development. This was the original platform used when 6bone access was established, but the 6bone tunnel is now moved to the Cisco router due to obvious reasons.
- Solaris 2.5/Ultrasparc 1 using the package SUNWipv6 version 5.2 and 5.3. The package is described in [8].
- Windows 95/FTP software protocol stack/x86. Ten Pentium II/300 MHz clients in the Multimedia Communication Lab are configured with NT/Windows 95 dual boot operation, and the FTP Software IPv6 stack is used on the Windows 95 configuration. This software enables dynamic configuration of IPv6 addresses for the PC clients. However, few appliations are available and the IPv6 API is poorly documented.

4 IPv4 Network

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. Each host which is IPv6 capable will have a special DNS record, showing the hosts IPv6 address. IPv6 will be the preferred protocol, but there will be many IPv4-only hosts in the Internet demanding IPv4 communication for several years. Thus, our experimental systems will all be configured with both IPv4 and IPv6 support.

IPv6 introduces a packet header with more functionality than the IPv4 header. Though the IPv6 headers have been stable for some time, the IETF still discuss how the new functionality shall be used, and how it shall be implemented. While this process continues, IPv4 must be an available protocol.

This means that each interface in the experimental network must have at least one IPv4 address. In the experimental network there must be room for experiments with mobile IP. These hosts will connect to different networks, and they must have one IPv4 address for each available network. However, mobile nodes will occupy only a limited IPv4 name-pool since we use dynamic allocation of these addresses by means of DHCP.

As a start we have 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 network between the different sites according to Table 2. The different sites/projects in Tromsø, Trondheim, Bergen and other places may get addresses from other sources, like Uninett.

Table 2: IPv4 address plan, 128.39.11.0/24

Nodes	Block	Network	Number of nodes	Comments
0-63	26	MMCL1	64	Primary IPv6 network (stable!)
64-91	27	MMCL1-mobile	32	Experimental IPv6 for mobile clients
92-127	27	MMCL2	32	Secondary IPv6 network (experimental)
128-191	26	IMiS network	64	IMiS kernel network
192-223	27	Not allocated	32	Can be used for test purposes
224-227	30	MMCL1-NTNU		Link network
228-231	30	MMCL1-UiB		Link network
232-235	30	MMCL1-IFI/UiTø		Link network
236-239	30	MMCL1-TF&U		Link network
240-243	30	MMCL1-UNIK		Link network
244-247	30	MMCL1-IMiS		Link network
248-251	30	MMCL1-MMCL2		Link network
252-255	30	MMCL1-Uninett		Link network

5 IPv6 Network

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, termed “6bone”. This 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. This segment is supposed to cover the need of all norwegian ISPs.

5.1 The IPv6 address structure

According to [13], IPv6 unicast addresses are aggregatable with contiguous bit-wise masks similar to the IPv4 addresses under Class-less Interdomain Routing [14]. There are several forms of unicast addresses in IPv6. These are:

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

Each IPv6 address is an 128bit 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. According to[13], the following address format should be used.

Table 3: IPv6 address format

Bit	Purpose	Comments
3	FP	Format prefix (3 bit) for aggregatable Global Unicast Addresses
13	TLA ID	Top-Level Aggregation Identifier
32	NLA ID	Next Level Aggregation Identifier
16	SLA ID	Site level Aggregation Identifier
64	Interface ID	Interface identifier

The **`3ffe:2a00::/24`** network block does not fit into the sceme of Table 3. We therefore suggest the IPv6 address plan which is described in Table 4.

5.2 National IPv6 connectivity

The Norwegian Internet Service Providers (ISP) are connected through the Norwegian Internet Exchange point (NIX) for IPv4 traffic, as shown in Figure 4.

Each ISP (e.g. Uninett) have separate lines for international connectivity. The different ISPs will likely connect to the IPv6 experimental network, and we suggest a similar IPv6 network structure for this purpose. Using this approach, each ISP connecting to the experimental IPv6 network must achieve 6bone connectivity through their own lines, while national traffic is handled by the main IPv6 router as shown in Figure 5.

An alternative in the short term would be to terminate all national traffic in the MMCL main IPv6 router

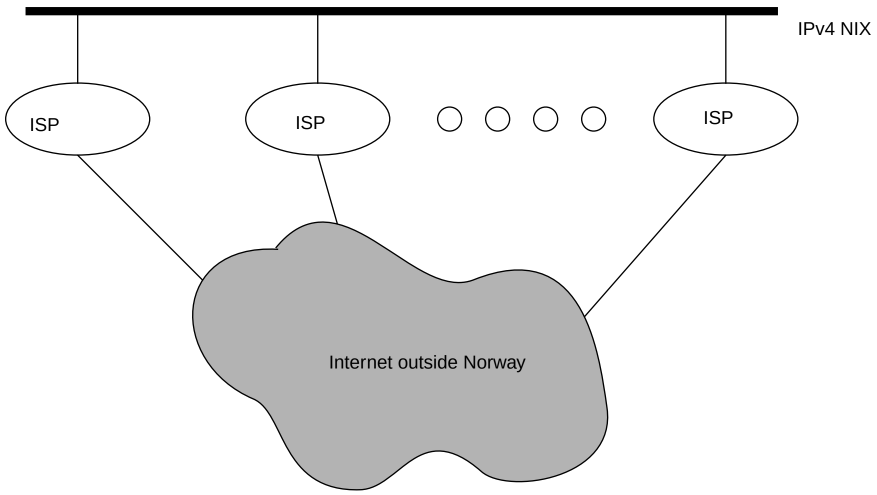

Figure 4 Norwegian IPv4 Internet Exchange. NIX

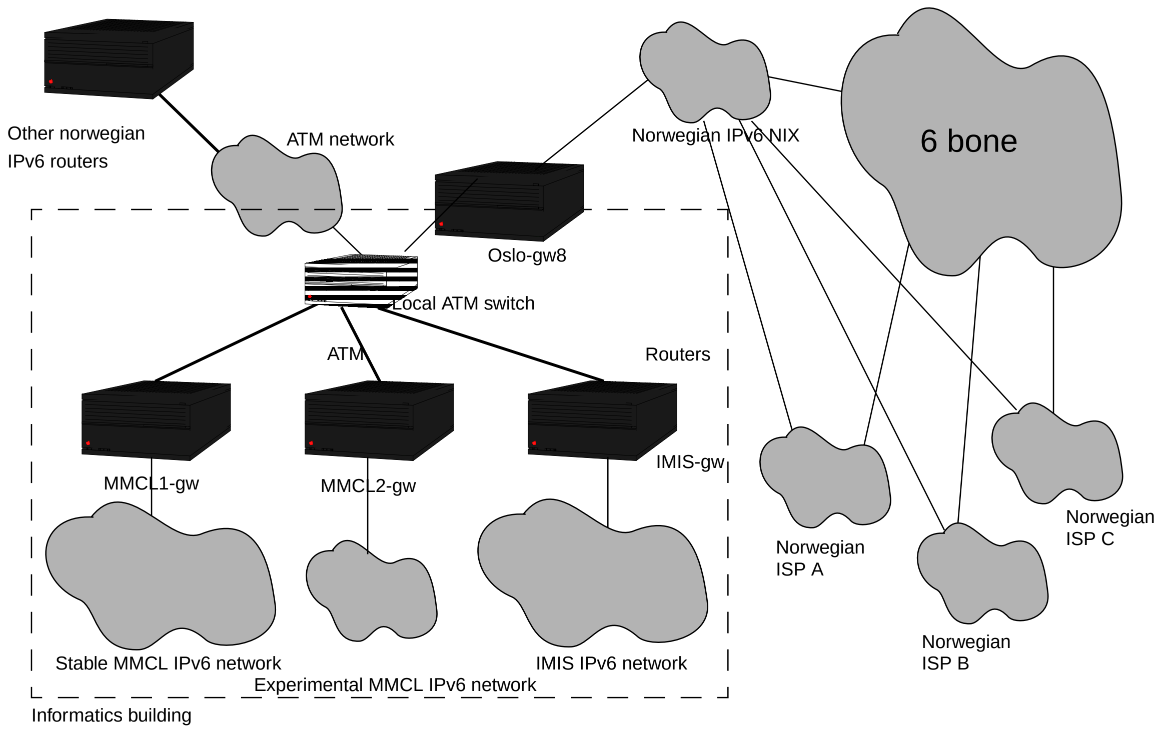

Figure 5 Suggested interconnection of IPv6 networks in Norway (IPv6 NIX)

where ISPs are assigned portions of the national address space according to the plan proposed in the next section. This approach is shown in Figure 6. In the long term, an IPv6 NIX is the preferred solution, and policies regarding wether experimental activity outside the Uninett domain can be allowed on the experimental IPv6 infrastructure is decided by Uninett since they provide international IPv4 connectivity for the IPv6-in-IPv4 tunnel to the test network. This has yet to be decided by Uninett and no non-Uninett sites are currently connected to the Uninett experimental IPv6 network without explicit permission from Uninett.

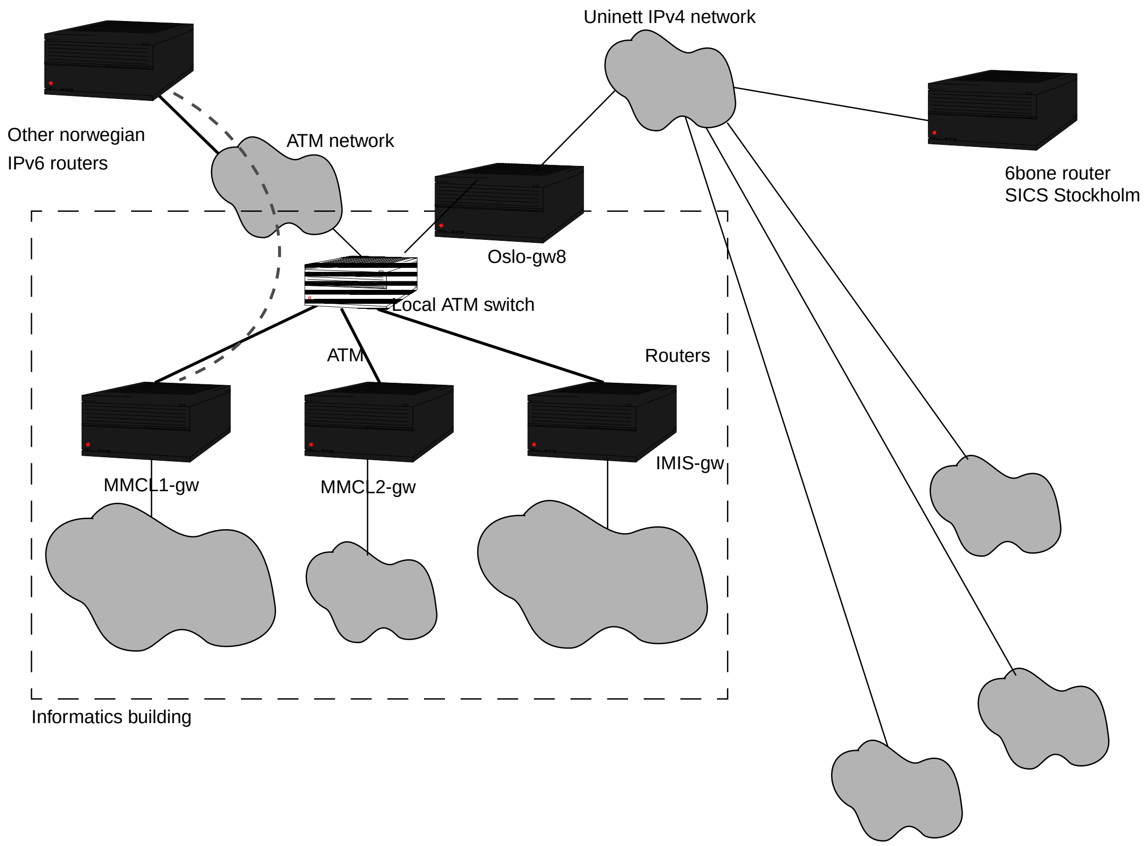

Figure 6   Possible short term interconnection of IPv6 trial networks in Norway

5.3 International connectivity

We have allready received requests from organizations in other countries currently under the Nordunet-domain, wanting to connect to the 6bone through our network. Currently, we have to defer such requests until a policy has been decided. Of the same reasons discussed for national connectivity, such requests must be handled by Uninett since we use their IPv4 access and address space.

5.4 Norwegian IPv6 address structure

Since the first connection to 6bone from **`la1ad.uio.no`** in May 1997, Jan Marius Evang has been assigned the responsibility of the 6bone name space for Norway. This assignment has been done in coordination with Uninett[9]. Norway is currently assigned the **`3ffe:2a00::/24`** from 6bone and the proposed address plan is shown in Table 4.

Table 4: Norwegian standard IPv6 address plan

Bits	Value	Number of Network	Number of nodes	Comments
24	3ffe:2a00		N/A	National prefix under 6bone
16	0-fff	65536	N/A	Number of Internet access providers
24	0-ffffff	16777216	N/A	Number Internet access provider subnet
64	0-ffffffffffffffff	N/A	2^{64}	Number of hosts on each subnet

This national IPv6 network is sub-divided into ISP networks and ISP subnetworks. The proposed address structure shown in Table 5, is a modification of the proposed address plan shown in Table 4 since we want to support a higher number of ISPs. Following [13], we could only support 256 ISPs in Norway under 6bone. With the current assignment this number is increased to 64K.

The individual ISPs are then free to subdivide their address structure as they like, but we recommend that the proposed Uninett model will be followed by all ISPs. This model is shown in Table 5 and leaves room for 4096 “customer networks”, each with 4096 subnets. On each subnet, the full 64 bit interface address can be used.

Table 5: Norwegian recommended subnett plan

Bits	Value	Comments
16	3ffe	6bone
8	2a	National prefix
16	0:0:0:1	ISP part (e.g. Uninett)
12	0:0:1	ISP site (e.g. UiO)
12	0:0:1	Site subnett (e.g. MMCL1)
64		Interface address (e.g. MAC address)

An example of this address assignment is given in Table 6.

Table 6: Example 6bone address assignments

Top Level Aggregation Identifier (TLA)	Pseudo TLA (pTLA)	Next Level Aggregation (NLA)	Network and site	level aggregation	64 bit 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:IMIS

An exaple IPv6 address from this structure is the stable IPv6 router in the MMCL lab. It has the structural location 6bone:No:Uninett:UiO:MMCL1:MAC-address, which corresponds to the IPv6 address **`3ffe:2a00:0100:1001::0010:2fed:4c30,`** where the last 64 bits of the address is derived from the hosts MAC-address as suggested in [15].

6 Conclusion

Our main contribution is establishment of the IPv6 address plan for the experimental IPv6 network in Norway. We have also given our recommendations to required network equipment to establish connectivity within the IPv6 trial sites. The main IPv6 router in the experimental network (**mmcl1-gw.ifi.uio.no**) router currently terminates the IPv6 tunnel to 6bone trough SICS, and new IPv6 sites under the Uninett domain are welcome to set up tunnels trough this 6bone access point. Request for IPv6 connectivity to your academic institution can be done by mail to **ipv6-drift@ifi.uio.no**.

The experimental IPv6 network is a great opportunity for the Norwegian research community to get involved with Internet-2 related research, and we look forward to obtain IPv6 connectivity with the other research institutions. We will strive to continnously update the project homepages [16][17] to reflect current status of the network as results emerge. We look forward to interesting projects and good research collaboration in the national IPv6 network!

Acknowledgments

Kjetil Otter Olsen, USIT, University of Oslo, has provided insight in issues related to ATM in general and to the Uninett, Supernett and Nordicom networks as well as router configuration of Uninett access switches together with Reier Rødland also from USIT. Olav Kvittem and Petter Kongshaug at Uninett have provided insight in the network infrastructure of Uninett, and assisted with funding to the MMCL lab. Both the MMCL lab and the IMIS and ENNCE projects are supported by the Norwegian Research Council. In addition we have received valuable comments from researchers and people responsible for computer facilities at the involved institutions.

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