Contract Number: IST-2000-26417
Project Title: GN1 (GÉANT)

Deliverable D9.5

Proposal and implementation plan for the migration of current MBS

Deliverable Type: PU-Public
Contractual Date: 30 June 2001
Actual Date: XX October 2001
Work Package: WP8
Nature of Deliverable: RE - Report

Author: Roberto Sabatino   DANTE

Abstract:

> *This Deliverable outlines the options available to replace the current TEN-155 Managed bandwidth Service which is based on ATM technology. Given the setup of GÉANT, it will not be possible to run an ATM-based service and therefore alternative solutions are necessary to fulfill the requirements of international user groups currently using the TEN-155 MBS. The Deliverable analyses options available using optical transmission technology and then goes onto focus on the deployment of MPLS techniques. It outlines the interactions required between the GÉANT network and the NRENs as well as outlining which service management issues need to be solved prior to offering a full operational service to the prospective end users*

Table of Contents

EXECUTIVE SUMMARY

The TEN-155 Managed Bandwidth Service (MBS) offers the possibility to set up connections between end-users in different countries with guaranteed quality of service. The guarantees offered are in terms of offered bandwidth, one-way delay, one-way packet delay variation and packet loss. The Managed Bandwidth Service also allows the setting up of Virtual Private Networks between participating sites, which enables for example the testing of new protocols without interfering with the production IPv4 traffic on TEN-155.

The TEN-155 Managed Bandwidth Service is implemented using ATM technology on a complete end-to-end path, or at least on one which terminates close to the user. End users work within institutes connected to NRENs which are in turn connected to TEN-155. It is therefore clear that the TEN-155 MBS is in reality a service spanning multiple management domains. The MBS is implemented as a combination of edge-to-edge services where each domain is responsible for the configuration of its own component.

The TEN-155 MBS can be seen as offering 2 basic services:
- Guarantees in terms of bandwidth, loss, delay, and delay variation for IP traffic between end-users spanning multiple management domains;
- Set up of layer-2 Virtual Private Networks with or without bandwidth guarantees, such as to allow the testing of native protocols without interfering with the IPv4 traffic handled by the production routers.

On GÉANT these service requirements have been confirmed. This has been shown by experience in TEN-155, from interviews with international user groups in the context of the SEQUIN project and from the requirements of the GÉANT working groups such as those testing native IPv6 or differentiated services Per Hop Behaviours (PHBs).

The first of the required services (IP traffic guarantees) is being addressed in the Work Item on Premium IP (Deliverable D9.1) so this deliverable will focus on the delivery of the second type of required service – i.e. the isolation of traffic at protocol level. An outline of the possible options ranging from implementing an SDH overlay network on GÉANT to the use of MPLS techniques for meeting this requirement are described. We also present recommendations for implementation in GÉANT together with a list of further work to be done prior to implementation of a full service.

1. INTRODUCTION

The TEN-155 Managed Bandwidth Service (MBS) [MBS] allows the setting up of connections between end-users; these connections span multiple management domains and are provided with guarantees in terms of available bandwidth, loss, one way delay and delay variation. The MBS also allows the setting up of Virtual Private Networks (VPN) between groups of end-users which, in turn, permit the testing of new communication protocols or mechanisms without interfering with the standard IPv4 routing/forwarding. The MBS, being an end-to-end service spanning multiple management domains, is implemented as a combination of edge-to-edge services using ATM technology. The need to replace the current MBS based on ATM with a different technology is a consequence of the following:

- Many NRENS are abandoning the use of ATM within their own backbones, which means that an end-to-end service using ATM cannot be supported in many locations;
- GÉANT will not have ATM capability in the backbone because of the lack of ATM interfaces for IP routers running at capacities equal to or greater than 2.5Gbps.

TEN-155, with its ATM capability, will cease to exist on 30 November 2001 but the need to support end to end Quality of Service guarantees is still a requirement for the NRENs has been shown by the results of interviews with several international user groups conducted in the context of the SEQUIN project [SEQUIN]. The following sub-sections will outline the implementation details of the TEN-155 MBS and the MBS requirements for GÉANT.

1.1 The TEN-155 Managed Bandwidth Service

This section will focus only on the management and administrative solution used to provide the end-to-end MBS service, as the technology used – ATM – is now well understood and documented.

The TEN-155 MBS [MBS] allows the definition of Virtual Private Networks linking members of a project and supplying them with network resources defined as bandwidth requirements, lifetime of the established connections, traffic profile and a complete set of network parameters [MBS].

The MBS is an end to end service. Its availability depends not only on the TEN-155 network but also on the NREN network infrastructure and technical and human resources within the TEN-155 community. MBS' main effect is extending coverage of ATM based connections and virtual private networks to all NRENs connected to TEN-155.

NRENs connect to the TEN-155 MBS via access ports, whose usage must be authorised by a person responsible for the national ATM service. For the international path DANTE is the responsible organisation (acting on behalf of the QUANTUM consortium). DANTE also co-ordinates interaction with Access Port Managers (APMs) in the NRENs for authorisation and other purposes. Connections can in principle be established directly between network equipment belonging to the project and that of the TEN-155 network. In that scenario, provision of national transit and access to the TEN-155 Point of Presence is the responsibility of the project.
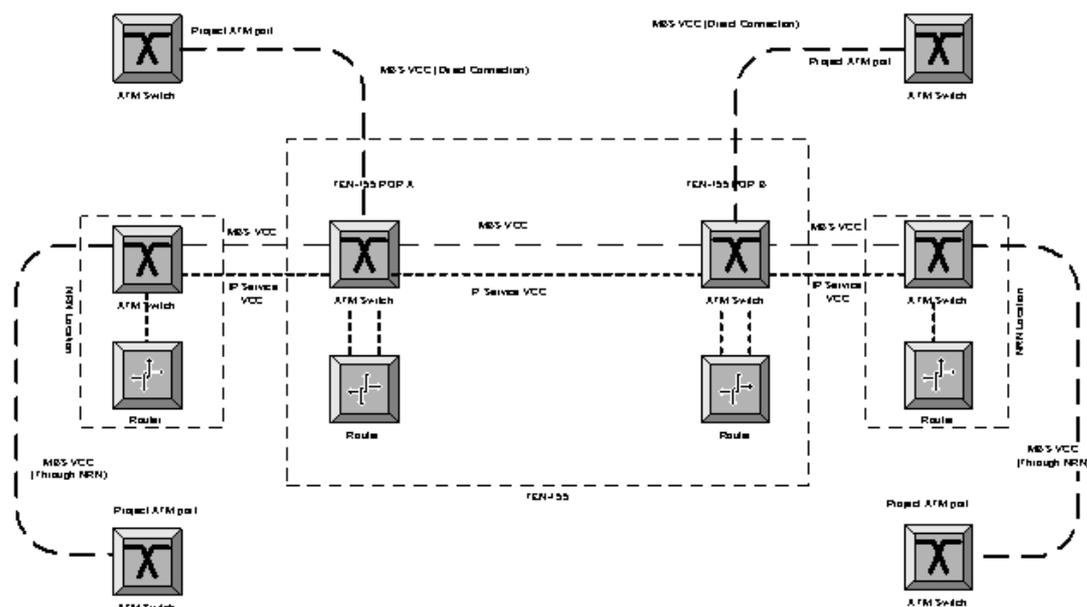
Figure 1: MBS administrative domains

Figure 1 identifies the different network equipment involved (routers, ATM switches) and the ATM links to be established when the connection is made directly to a TEN-155 port (located in the national TEN-155 Point of Presence) or when the NREN is used to provide transport between the project port and TEN-155 port. In this case the TEN-155 port acts as the demarcation point between the national and the international paths.

The maximum amount of bandwidth allocated at any one time at any NREN access port is limited to 20% of the access capacity.

The establishment of the end-to-end connection depends on the availability of the requested options all along the path through several different administrative domains between end points. This means that available options for connections depend on the ATM service implemented or used by the NRENs involved. Support for the following elements has been built into the TEN-155 backbone:

- Depending on how the connection is established and released:
    - Permanent connections (PVC), established by the network operations centre by using network management tools.
    - Switched connections (SVC), established by user ATM equipment using signalling protocols (UNI3.2 or UNI 4.0) .

- Depending on the duration of the connection (PVCs only):
    - Scheduled occasionally, start time and end time known.
    - Permanent static, start time known, end time open.
    - Permanent periodic, start date for period known, end of service date open, time pattern specified with periods of connection availability on a daily basis, weekly, etc.

- Depending on the ATM type of connection:
    - Virtual Channel Connections (VCC), the minimum element able to transport cells. Every ATM connection is composed of at least one VCC.

- o Virtual Path Connections (VPC), identifier of a set of VCCs. VPCs are only available for PVCs.

- Depending on the number of end points:
  - o Point to point, one source, one end point.
  - o Point to Multipoint, one source, many end points

- Depending on the requested transfer capability (with specifications according to standards ITU I.371, ITU I.356)
  - o Deterministic Bit Ratio (DBR) with QoS-1, traffic parameter: Peak Cell Rate (PCR).
  - o Statistical Bit Rate (SBR2 or SBR3) with QoS-3, traffic parameters: Peak Cell Rate (PCR) and Sustained Cell Rate (SCR).
  - o Available Bit Rate (ABR) with QoS-3, traffic parameters: Peak Cell Rate (PCR) and Minimum Cell Rate (MCR

The management interfaces are a critical component for the success of the service. Some important procedures include limiting the initial contacts to the project participants and DANTE until a clear project plan is outlined. From this moment, information can be presented to the NREN responsible person in an adequate way. Any national issues such as allowing end-users to connect directly to TEN-155 bypassing the corresponding NREN, are resolved by the NREN in question.
Three interfaces are needed, as persons and contact points during the process:

- A Group Network Manager (GNM) from the project side,
- an ATM service co-ordinator from the NREN and
- a single contact for the ATM TEN-155 service provided by DANTE.

Organisations participating in a project identify a Group Network Manager whose role is the co ordination of all the members in the project and communication with DANTE.

The primary channel of communication is between the GNM and DANTE. DANTE contacts the responsible person for the ATM service of the NRENs involved and stays in regular contact with the GNM, as the single contact point to the project.

To make the initial request the GNM sends DANTE a minimum set of information which is used to help evaluate the project's feasibility, the amount of resources needed and a cost estimation in case additional equipment or resources are necessary. Web forms or electronic mail are used as tools for requesting submission and tracking.

Similar services to the TEN-155 MBS have been deployed and are in operational or pilot service status in some European Academic networks. When the project has sites in these networks, references to local procedures guide users to the information they need to obtain service. In those networks without an operational MBS-equivalent service, initial contacts with the ATM service co-ordinator from the NREN are established by DANTE to determine necessary and available resources (human and technical) to connect the project member.

Information about the project, to describe the technical set-up, may be required for participants in different countries. The GNM is responsible for information gathering within the project.

Once the project feasibility is verified, necessary arrangements may be made directly between the NREN's ATM service co-ordinator and the GNM to implement the connection of each site with the NREN port. In case of difficulties, the GNM-DANTE channel remains the priority means of communication. This avoids overloading the ATM service co-ordinator on the NRN side.

The result of the service request process is an activity plan to be performed by the involved parties, identifying action points, resources, timelines and costs. This plan must be accepted by all parties and provides a definition of the project.

Once the project is running, service management is done by the TEN-155 ATM Network Operations Centre (ATM NOC).

1.2 GÉANT Requirements for MBS

Any service equivalent to the MBS offered to end users in NRENs will necessarily have to deal with multiple administrative domains and also with a mix of technologies. In the current era of Gigabit networking it is not possible to assume that the technology along the path from a user in one domain to another user in another domain, crossing GÉANT, will be uniform. Some NRENS may still have an ATM based backbone, others may use SDH networks, others including GÉANT will implement a mix of optical networks and SDH networks. Even if two networks share the same technology at the data-link layer (i.e. ATM or SDH), the switching or routing technology may well be different in each administrative domain. It is now a reality that Cisco routers are no longer the default choice for backbone routing equipment, in fact Juniper has acquired a significant portion of this market.

The SEQUIN project [SEQUIN] aims to analyse and implement QoS for end users in such multi-management and multi-technology environments. One of the first steps of the project was to define QoS, and to this end an interview with several international user groups has been conducted to understand their requirements for QoS. All of the groups interviewed have responded that their requirements were to carry IP traffic with a bandwidth guarantee. Many user groups responded that in addition to a strict bandwidth guarantee they also require guarantees on one-way delay, one way delay variation and packet loss. Thus the international user groups interviewed were interested in either the emulation of a leased line to carry IP traffic or the availability of a minimum bandwidth guarantee between two points on the network to carry IP traffic.[SEQD2.1]

From the GÉANT working groups it has also emerged that there is the requirement to be able to set up international testbeds to carry traffic to test protocols or mechanisms that in normal circumstances would interfere with the normal production IP traffic. This is for example to test native IPv6, or to test Differentiated Services Per Hop Behaviours or implementations of MPLS techniques on routers. These testbeds may or may not require bandwidth guarantees; the main requirement is to obtain isolation at protocol level from the normal IP traffic carried on GÉANT and the NRENS.

To summarise, two requirements have emerged:

1. To provide guarantees for IP traffic, in the form of leased line emulation or a simple minimum bandwidth guarantee
2. To provide testbeds with isolation at protocol level from the standard IP traffic on GÉANT.

The first item is being addressed within SEQUIN and the GÉANT working groups who are making use of the SEQUIN results and working towards the definition and implementation of a Premium IP service [GEA-D9.1].

This deliverable will therefore focus on the provision of testbeds to offer isolation at protocol level from the standard IP traffic for end-user sites.

2.   OPTIONS FOR A GÉANT MBS

We outline the technology options that have emerged both from testing activities and from discussions with equipment vendors that took place during the procurement phase of GÉANT. These options all offer the possibility to dedicate bandwidth with guarantees to end-users. The objective is to obtain a technical and management solution that has the following features:

*   Scalability, i.e. possibility to support numerous dedicated connections in each location;
*   Possibility to offer a high range of bandwidth values, for example from 2 Mbps to 622 Mbps;

- Same flexibility as that offered by the TEN-155 MBS whereby any dedicated bandwidth which is not used can be utilised by the standard Best Effort IP service;
- It must be available in all GÉANT locations. This is not a strict immediate requirement but is a target to be achieved within the lifetime of GÉANT;
- It must be compatible with what is offered at a national level by the connecting NRENs, in order to be able to offer an overall end-to-end service;
- When required, it must be able to offer bandwidth guarantees.

The following subsections outline the possibilities available using developments in optical networking technology, standard SDH technology and use of MPLS technology on IP routers.

For some time now a considerable amount of Research and Development effort has been put into investigating options for dedicating capacity to end-users at the optical wavelength level and how to integrate the management of the optical transmission layer into the IP layer. This is normally referred to as G-MPLS (Generalised MPLS) although no implementation is as yet ready for neither deployment nor testing. We will however illustrate practical options available at the optical level to dedicate capacity to end-users. In this context it is important to outline that GÉANT's 10 Gbps and 2.5 Gbps circuits are delivered via DWDM equipment from Nortel and Lucent. The equipment from these vendors has built-in capability to multiplex capacity on a single wavelength, thus offering potentially interesting options for providing dedicated bandwidth for traffic flows. We outline the possibilities that have been explored theoretically, but not tested by the GÉANT working groups.

2.1 Nortel optical combiners

The current fibre networks being deployed on a pan-European scale use Dense Wave Division Multiplexing (DWDM). That is, on each fibre several wavelengths provide multiple communication channels. The capacity associated with a wavelength can be either 2.5 Gbps or 10 Gbps. Several carriers use Nortel Optera DWDM equipment that uses 10 Gbps wavelengths as the basic transport capacity in optical fibre backbones. If a customer purchases a 2.5 Gbps wavelength service, this will be transported within a 10 Gbps channel in the network and presented to users with 2.5 Gbps SDH framing using *optical combiners*.

If the carrier sells 5 x 2.5 Gbps between the same pair of nodes the Nortel equipment will allocate 2 x 10 Gbps, i.e. 20 Gbps to provide the 5 x 2.5 Gbps to its users.
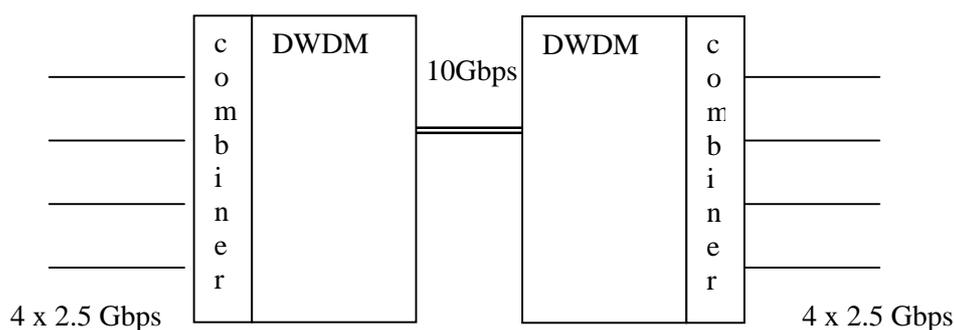

Figure 2. Nortel Combiners

The combiners are part of the Nortel Optera equipment, and therefore can only be managed by the entity which manages the Nortel equipment. In the case of GÉANT this corresponds to the carrier from whom the 10 Gbps or 2.5 Gbps has been purchased. In practice, this is equivalent to purchasing 4 x 2.5 Gbps rather than 1 x 10 Gbps which implies a significant increase of the cost of the total capacity.

This solution has several drawbacks:

- It has poor granularity, in fact it is only possible to allocate 2.5 Gbps;

- It has poor scalability, in fact at each node with 10 Gbps capability only 4x2.5 Gbps circuits are extractable.
- It is possible to extract 2.5 Gbps only out of a single 10Gbps channel. It is not possible to obtain a 2.5 Gbps connection which would span more than one 10Gbps connection. In the case of GÉANT, it would be typical to request a dedicated connection between nodes with several 10 Gbps hops in between.
- It is not flexible because any unused dedicated bandwidth is not available to the standard IP service. In fact it is a strict and static split of the available capacity.
- It is not available in all GÉANT locations, only in those where wavelengths are purchased and therefore a significant part of the GÉANT geography would be excluded from the use of this service

2.2 Lucent Lambda-Unite

In optical fibre networks implemented using Lucent OLS DWDM equipment, a mix of 2.5 Gbps and 10 Gbps wavelengths can co-exist within the fibre systems. If a customer purchases 2.5 Gbps, this will be provisioned via a clear 2.5 Gbps channel in the Lucent network instead of 10Gbps as in the case of an optical network based on Nortel Optera. Therefore if it were required to obtain 10Gbps as 4 x2.5Gbps, it would be necessary to actually purchase 4 x 2.5Gbps from the relevant carrier. In September 2001 Lucent is releasing an optical access device called Lambda-Unite which can multiplex Gigabit Ethernet and SDH presentations into a wavelength. This technology, whilst certainly of potential interest, is unproven operationally. With this technology, it is potentially possible to extract out of wavelength a Gigabit Ethernet connection and any other SDH-frame based connection. It is relatively clear how the solution would work on a point-to-point basis but it is not clear, as in the case of Nortel Optera, what would be the solution in the case of a service request spanning multiple wavelength connections.

This issue is depicted in the following figure whereby it is envisaged to provide Gigabit Ethernet connectivity between endpoints A and B which are connected via $\lambda1$ and STM-1 connectivity between endpoints C and D which are connected via $\lambda1$ and $\lambda2$. It is technically understood how to provide the dedicated Gigabit Ethernet (GE) connectivity between endpoints A and B. The GE connection is extracted from the capacity available on wavelength $\lambda1$, and the remainder of the capacity on that wavelength is usable for other dedicated connections. The other connections include one which supports the normal IP service. On the other hand we have not yet understood how to provide the STM-1 connectivity between end points C and D which span both $\lambda1$ and $\lambda2$. This would be a very typical requirement for GÉANT.

This solution has several drawbacks as in the case of Nortel Optera, with the additional obstacle that the product is as yet unproven operationally. It is nevertheless a possible option though a proposal that is worth investigating in the future.
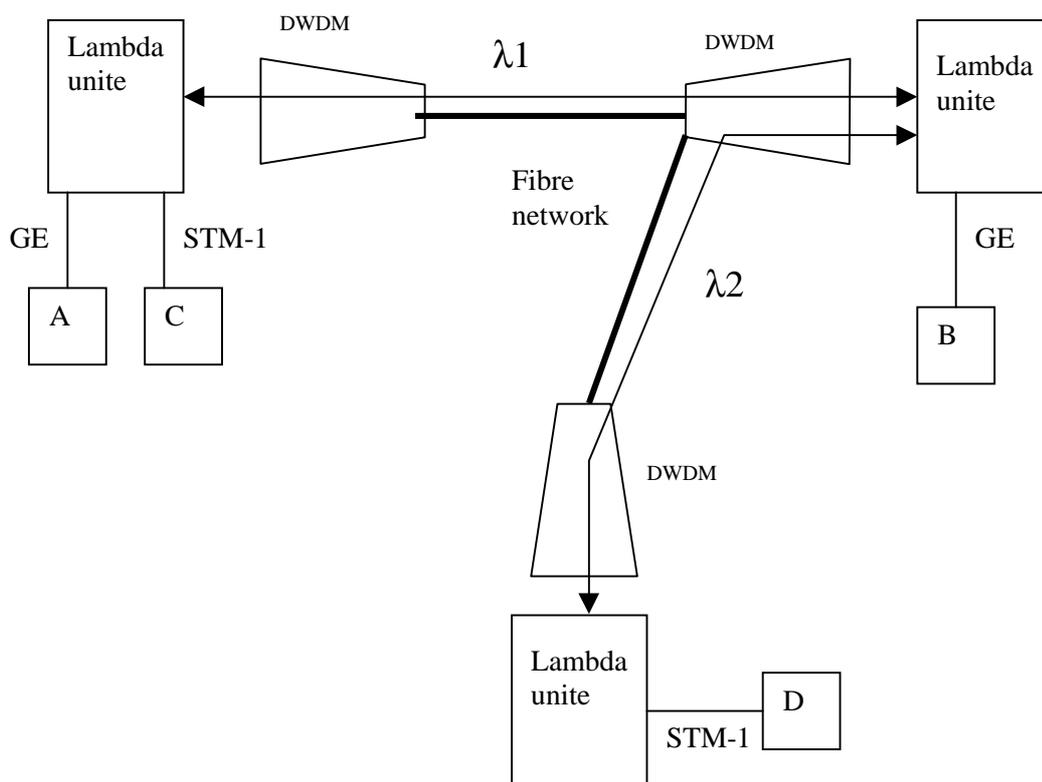
Figure 3. Use of Lucent lambda-Unite

This solution has several drawbacks as in the case of Nortel Optera, with the additional obstacle that the product is as yet unproven operationally. It is though a possible option that is worth investigating in the future.

2.3 SDH overlay network

SDH services are usually built using SDH multiplexers on a network based on wavelengths. Wavelengths connect the SDH multiplexers, which construct an overlaid SDH hierarchy over the single (or multiple), 2.5 Gbps or 10 Gbps communication channels provided by the wavelengths. The provider of the SDH service is then able to offer capacities in the range 2 Mbps to 2.5 Gbps to its customers. It is a proven methodology, already widely adopted by many carriers across Europe. In addition, G-WIN implements a MBS using this technique.

It is a very costly solution, as it requires an SDH NOC function, procurement and maintenance of the SDH equipment. The main drawback of this solution is that it is not flexible in that any dedicated but unused capacity is not available to the best efforts IP traffic. In addition, it would increase the complexity of the GÉANT router set up because the routers would need to have multiple lower speed interfaces instead of a single interface at high capacity as depicted in the following figures. The figures outline how a 10 Gbps channel is split up into 3 x 2.5 Gbps which are used for the normal IP service, and the remaining 2.5 Gbps is used to provide capacities ranging from 2 Mbps to 622 Mbps.
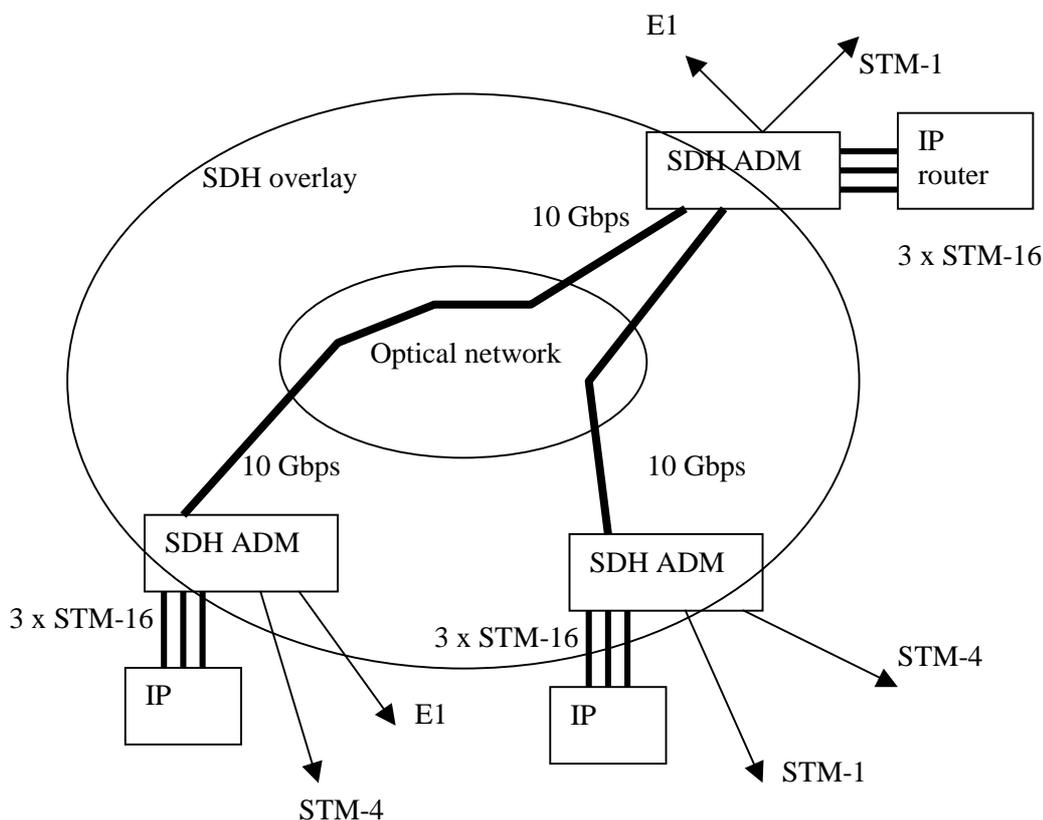
Figure 4. Example of SDH overlay network

2.4 MPLS/CCC

Router manufacturers are investing a lot of resources into the development of Multi Protocol Label Switching (MPLS). This technology is still in the standardisation process but both Juniper and Cisco implement solutions corresponding to the parts of the MPLS specification that have been standardised already. The GÉANT Technical Working Groups have conducted extensive testing of several of the MPLS techniques [MPLS-TEST].

Router manufacturers are also implementing additional features, with the aim to proposing them as IETF standards; some of these features are very promising as candidates for replacing features of the TEN-155 MBS. Specifically these are CCC for Juniper and ATOM for Cisco. GÉANT will be implemented with Juniper routers so we focus on the CCC implementation from Juniper.

CCC stands for Circuit-Cross-Connect which is a mechanism that allows a layer 2 technology to be transported across an MPLS enabled backbone/cloud. A backbone based on a mix of technologies (wavelengths, ATM, SDH, PDH) is able to transport data presented as frames, packets or cells as specified for a number of technologies from one point of the network to another. For example an ATM VC or VP can be transported, or an SDH connection, or an ethernet connection. The following figure shows an example:
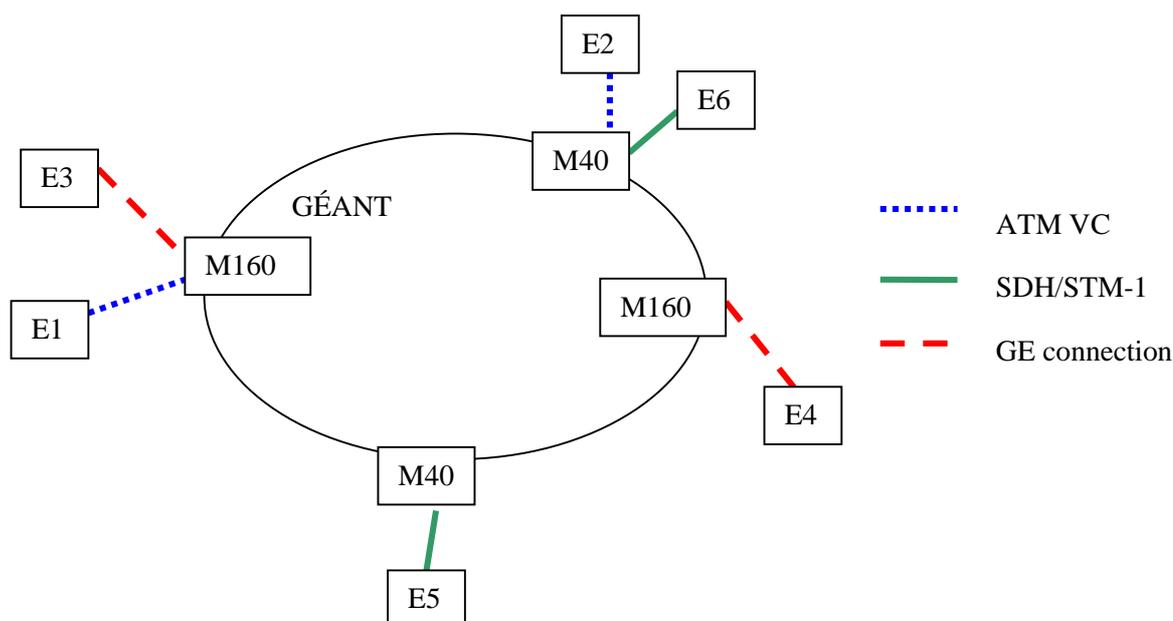
Figure 5. Overview of MPLS/CCC

The ATM connection is transported seamlessly between E1 and E2 across the MPLS enabled backbone. End systems E1 and E2 make use of this ATM VC as if it were provided by a standard ATM switch or ATM service. End systems E3 and E4 appear to be on the same GE LAN. End systems E5 and E6 appear to be connected by a direct SDH/STM-1 connection.

The MPLS/CCC technique has already been tested on Juniper M40 routers on TEN-155 in 1999 and worked well. The testing was performed on an older version of JUNOS than the current one and with older implementations of MPLS/CCC. More recent testing performed in July 2001 with newer versions of the software verified its capability to allow communication between native IPv6 routers.

Note that MPLS/CCC works at layer-2, i.e. it transports a whole SDH circuit or GE VLAN connection and for ATM it transports a VPC or VCC.
The MPLS/CCC solution is attractive because it fulfils all of the requirements set out at the beginning of the section, namely:
- It is scalable, i.e. in each location several requests can be fulfilled concurrently;
- It can offer a range of bandwidth values, for example from 2Mbps to 622Mbps;
- It has the same flexibility offered by the TEN-155 MBS whereby any dedicated bandwidth which is not used can be utilised by the standard Best Effort IP service;
- It can be made available in all GÉANT locations;
- It can be made compatible with what is offered at a national level by the connecting NRENs, in order to be able to provide an overall end-to-end service;
- It can offer bandwidth guarantees.

The solution has some drawbacks, listed below, but they are not considered to represent a serious obstacle to the use of these techniques to provide the requested service:
- The mechanisms are proprietary: MPLS/CCC from Juniper and MPLS/ATOM from Cisco do not interoperate. However the IETF is working towards standardisation of these techniques (L2 VPNs) and standard implementations are expected in early 2002.
- The proposal does not work across network management boundaries, hence MPLS/CCC is in reality an edge-to-edge service. This has to be combined with compatible mechanisms available in the connecting networks.

The remainder of this deliverable will explore in more detail the possibility of using MPLS/CCC to provide a replacement for the TEN-155 MBS.

3.   SUPPORT FOR CCC IN GÉANT AND NRENS

The following sub-sections will show, using the example of setting up an international IPv6 testbed, a suggested GÉANT set up and possible NREN configurations needed in order to implement the service end to end. Note that the NRENs are not required to implement the same mechanism as in GÉANT, it is only required that compatible techniques be deployed. Examples of such compatible techniques will be given. The sections will also outline how the requirements set out in the previous section can be fulfilled.

The example described concerns setting up of an international IPv6 testbed. The IPv6 testbed has nodes in GÉANT, with connections to NRENS who use the GÉANT/IPv6 backbone to reach one another.

The IPv6 nodes within GÉANT are inter-connected using MPLS/CCC and using ATM as the layer-2 technology. This is a practical example, connectivity between the IPv6 routers within GÉANT could also be achieved via Packet Over Sonet (POS) technology.

3.1 Connectivity between IPv6 routers within GÉANT

The testbed is composed of a core with IPv6 routers, each with a connection to its local NREN's IPv6 infrastructure. In essence the model of the IPv6 testbed is the same as the GÉANT IPv4 network. The testbed is (virtually) isolated at protocol level from the normal GÉANT IP service; the GÉANT routers do not need to understand IPv6.

Native IPv6 routers with ATM capability can be deployed in GÉANT PoPs. Virtual - over MPLS/CCC -ATM VCs can be set up between the IPv6 routers in the GÉANT PoPs .

The following figure outlines the set up within GÉANT of the native IPv6 testbed, without showing how connectivity to NRENS is achieved. It shows how the IPv6 router in the GÉANT PoP B is connected to the IPv6 routers in PoP A and PoP C.
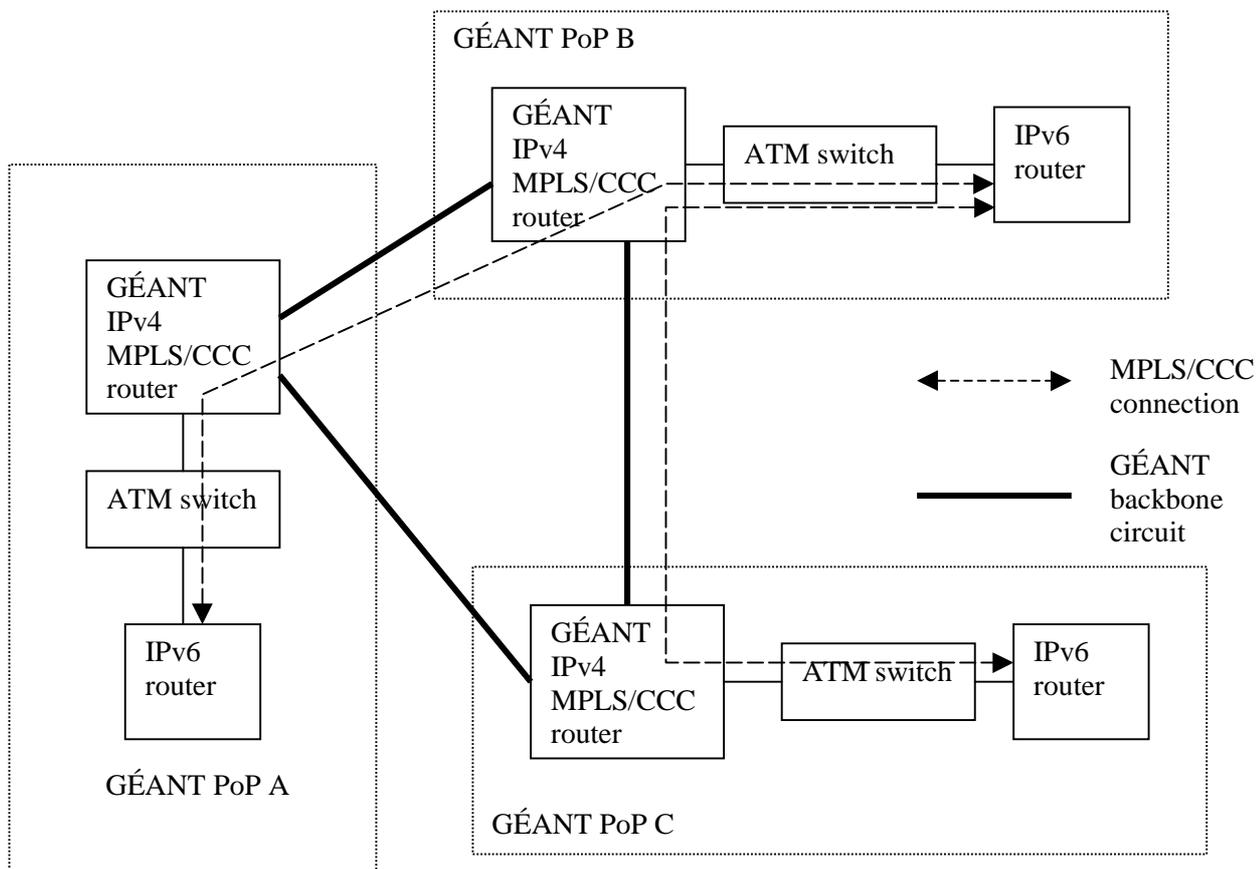
Figure 6: Use of MPLS/CCC to connect GÉANT core IPv6 routers

3.2 NREN options

To connect the NREN IPv6 router to the GÉANT IPv6 routers (or other NREN IPv6 routers) the NREN would have a dedicated local circuit to the GÉANT PoP, using ATM technology at speeds up to 622Mbps. Within the NREN, the IPv6 routers have three ways of connecting to the GÉANT IPv6 router and in each case MPLS/CCC techniques are not used on the network boundary between GÉANT and the NREN network:

- Via a native ATM connection if the NREN supports ATM. This ATM connection runs over the dedicated ATM local access circuit
- Via the entire dedicated circuit to the GÉANT PoP
- The NREN implements the same mechanisms as GÉANT and presents to DANTE a virtual ATM VC which is carried over an MPLS enabled cloud

3.2.1 Native ATM connection between NREN IPv6 router and GÉANT
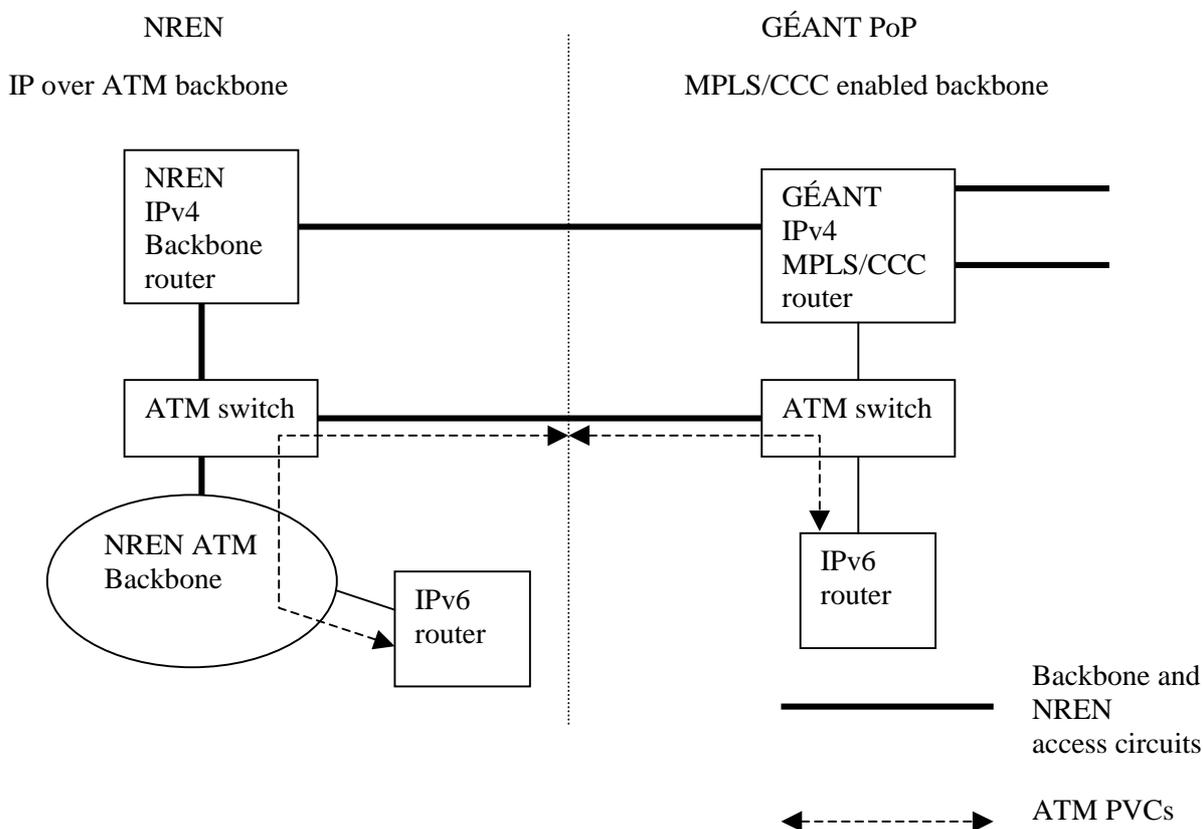
Figure 7: Connectivity between GÉANT and NREN via ATM PVC

In this example connectivity between the GÉANT and NREN IPv6 routers is obtained using standard ATM technology. The NREN has in place an ATM based backbone, and is able to provision an ATM PVC from the NREN IPv6 router up to the network boundary with GÉANT. GÉANT provisions an ATM PVC which initiates and terminates with both end points within the same PoP and which connects to the ATM PVC provisioned by the NREN.

3.2.2 Dedicated circuit between NREN IPv6 router and GÉANT IPv6 router
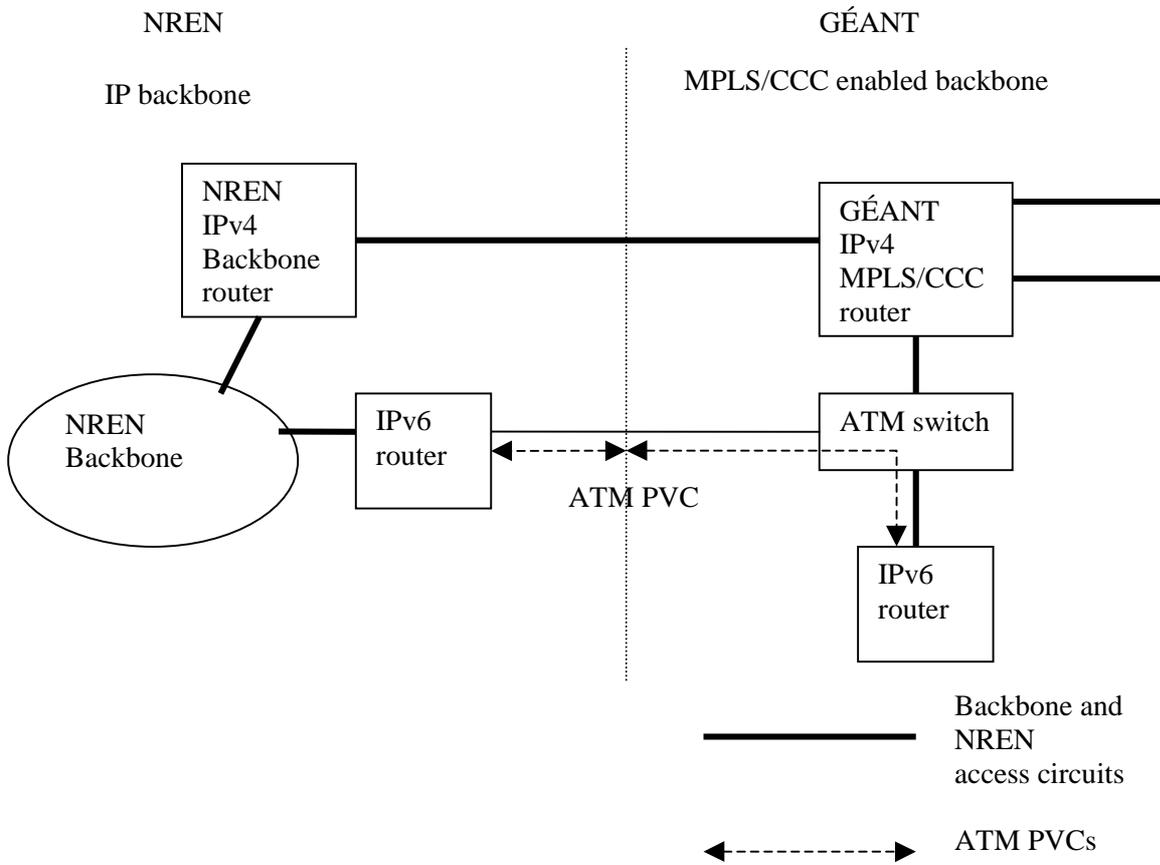

Figure 8: Use of entire dedicated circuit

In this example the entire dedicated circuit to the GÉANT PoP is used for the connection between the NREN IPv6 router and the GÉANT IPv6 router.
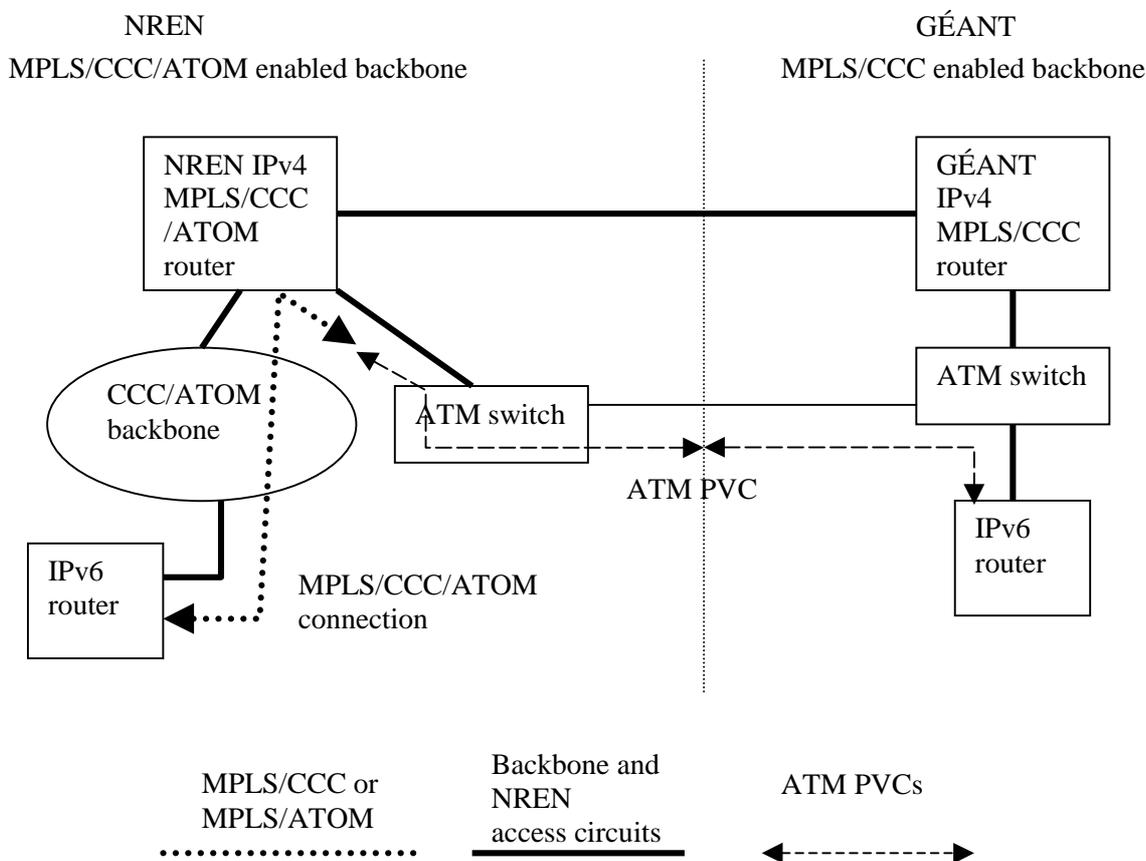
3.2.3 Use of MPLS CCC or ATOM within NREN backbone

Figure 9: NREN use of CCC or ATOM

In this example the NREN deploys a national backbone with MPLS/CCC or MPLS/ATOM capability. A virtual connection is set up within the NREN from the NREN IPv6 router up to the network boundary with GÉANT. Across the network boundary both parties (NREN and GÉANT) provision an ATM PVC in order to connect the IPv6 router in GÉANT and in the NREN.

3.3 General set up of interdomain MBS

By using MPLS/CCC in the GÉANT backbone and any combination within the NRENs of the three examples outlined in the previous section, it is possible to fulfill all of the requirements for the TEN-155 MBS replacement set out earlier in the document.

- Scalability, i.e. possibility to support numerous dedicated connections in each location. This is especially achieved by using ATM as the interconnection technology between NRENs and GÉANT for this service. Several ATM PVCs can be transported across this interface, serving numerous projects at the same time. By having an ATM switch in the GÉANT PoP, it is also possible to serve users that connect directly to geant, bypassing the NRENs. The same result can be obtained using technologies other than ATM, such as Frame Relay encapsulation on POS interfaces.
- Possibility to offer a high range of bandwidth values, for example from 2 Mbps to 622 Mbps. This is inherent in the use of ATM.

- Same flexibility as that offered by the TEN-155 MBS whereby any dedicated bandwidth which is not used can be utilised by the standard IP service. The capacity between the backbone routers on GÉANT is dynamically shared by the normal IP traffic and the traffic between the IPv6 routers. If the IPv6 routers on GÉANT do not exchange traffic, the full capacity is available to the normal IP traffic.
- It must be available in all GÉANT locations. This is not a strict immediate requirement but is a target to be achieved within the lifetime of GÉANT;
- It must be compatible with what is offered at a national level by the connecting NRENs, in order to be able to offer an overall end-to-end service. The three examples outlined above demonstrate that how different techniques offered by NRENs can be used to connect to the service provided by GÉANT.

The figure below summarises the proposed connection between GÉANT and NRENs. Within the NREN any of the techniques outlined above may be used to connect to the service offered by GÉANT.
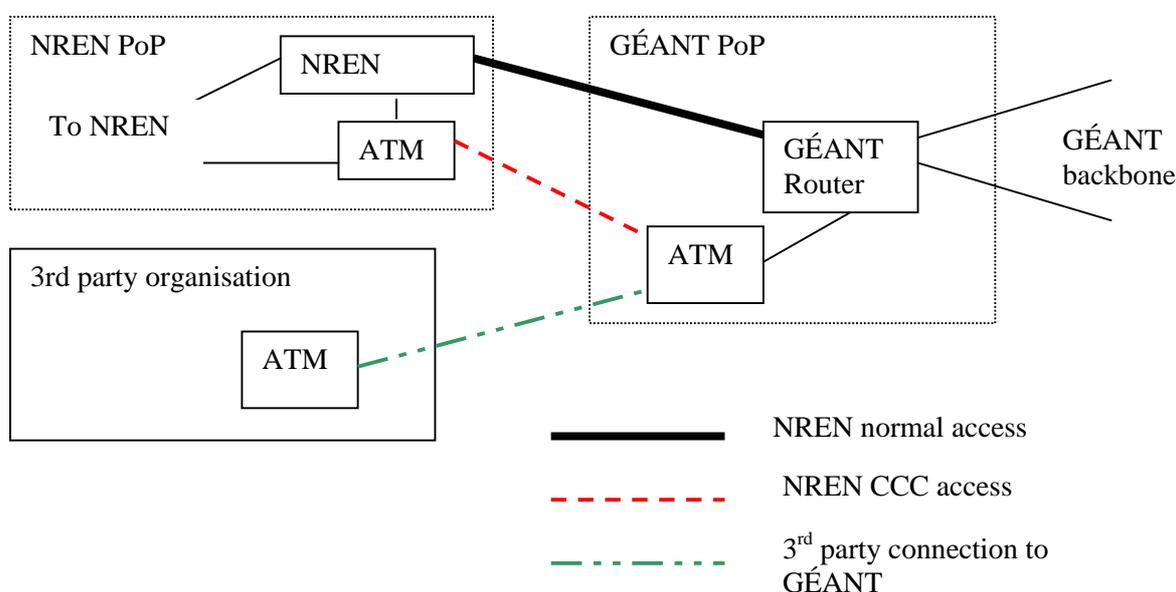

Figure 10: General set up of interdomain MBS

The NREN normal access to GÉANT will be the one carrying the production IP service (including standard IPv4, multicast and Premium IP). The capacity of this will range from 34 Mbps to 2.5 Gbps. The NREN CCC/ATOM access uses the additional access circuit used for the purposes explained here, and will typically have a capacity in the range 2 Mbps to 622 Mbps. The figure also outlines how a third party network within a country can connect to the GÉANT PoP and make use of the service outlined bypassing the NREN.

It is not strictly needed to equip the GÉANT PoP with an ATM switch, the same goal could be achieved by having a number of ATM ports on the GÉANT router. It is really a matter of evaluating the various costs.

Providing this service via an ATM interface to the NRENs ensures scalability, but other options are possible too. For example a number of POS ports on the GÉANT routers can be made available to deliver the service over a POS interface, or the service can be used with Frame Relay framing over a single POS interface shared with the normal access of the NREN.

4. STEPS TO BE TAKEN FOR THE DEVELOPMENT OF THE SERVICE

The service would be based on using the MPLS/CCC techniques described in this chapter, which at this stage are technically understood and have undergone a sufficient amount of laboratory testing. For the provisioning of the service the following items need to be addressed:
- The definition and execution of test case scenarios;
- Evaluation or development of service provisioning and monitoring tools;
- Service management.

4.1 Test case scenarios

This may also be called proof-of-concept testing. It is suggested to define two testing phases, whose goals range from verifying further the technology used to identifying technical improvements. An important goal is also to validate the service management procedures and provisioning and monitoring tools. It is suggested to subdivide the test case scenarios into two parts:
- An *alpha phase* which is concerned mostly with the technology issues and identifying which service provisioning and monitoring tools need to be developed. It is also concerned with understanding the service management issues. The alpha phase should include testing of the technology with a very limited number (at most 2) of international user groups with partners located in a limited number of GÉANT countries (3). To be useful the alpha phase must be able to fulfil the technological requirements of the user groups as well as identifying the management and service monitoring requirements of the users. Solutions for these requirements must be proposed. The service provisioning issues that need solving and the potential solutions must be identified and solutions proposed by the Network Operations Centre.
- A *beta phase*, where the proposed solutions for service management issues identified in the alpha phase will be deployed and verified. The same applies for the service provisioning and monitoring tools. It is suggested to co-operate with a small number of international user groups (up to 5 or 6) spanning a larger number of countries than in the alpha phase (5 or 6). The goals of the beta phase are to validate all the management and provisioning measures outlined in the alpha phase with a larger and more diversified user group.

It is suggested that the alpha phase starts in January 2001 with users with requirements to connect IPv6 routers. The users can be drawn either from participants in the GÉANT working group on IPv6 who will need to interconnect IPv6 routers, or from users participating in the planned 6NET project. The alpha phase should last for 3 months.

The beta phase should start immediately after the end of the alpha phase and connect to more user groups in more locations than in the alpha phase. It should last for 6 months.

4.2 Service provisioning and monitoring

The technology used for the service is based on MPLS. Tools for MPLS provisioning are available on the market, but these tools are not normally available in the Network Operation Centers of the NRENs and GÉANT– they normally resort to the use of a Command Line Interface (CLI) for configuration. The TEN-155 MBS service was based on ATM and the ATM NOC used a provisioning tool called NAVISCORE to configure the requested PVC. Use of these tools is recommended to minimise the human-error risk associated with CLI provisioning. A number of tools for MPLS provisioning are available, such as WANDL, but their suitability for the purpose of this service has to be verified. It may be necessary to develop additional features or different tools altogether.
Service monitoring is fundamental for the validation of the service provided to the end users. Also in this case there are products available on the market, but their suitability for the purposes of GÉANT has to be verified. If necessary, specific products should be developed.

4.3 Service management

Service management is as important as the technology and the service provisioning and monitoring, especially given that the service must work in a multi domain environment. Use of signalling to set up the connections is not recommended. Signalling for MPLS/CCC spanning multiple domains is not available, but even if it were it would not be recommended because of the total lack of multi-domain policy control implementations. The experience in TEN-155 with the availability of ATM SVCs has shown that in multi-management domains the static PVC approach across management domains is still preferable from a management point of view. It is therefore suggested to use the service management model of the TEN-155 MBS, which has proved successful in most cases. It is suggested to identify any weaknesses that users have encountered in this model of management and propose solutions to them.

5.   CONCLUSION AND FUTURE WORK

A possible technology solution for a replacement of the TEN-155 MBS has been outlined, together with the service provisioning, monitoring and management issues that are subject to further work. Further work needs to be done to finalise the most efficient way of interconnecting NRENS to the service offered by GÉANT, for example by choosing between ATM or Frame Relay technology. This document represents a proposal and outlines the necessary steps and timelines for the development of the proposed solution into a service.

A technique which is very similar to Juniper's MPLS/CCC or Cisco's MPLS/ATM is Cisco's UTI. UTI stands for Universal Tunnel Interface and it allows to achieve the same result that MPLS/CCC and MPLS/ATOM achieve, without having to run MPLS in between the end points of a connection. It is a new technology, available since August 2001, which has not yet been tested. It has both advantages and drawbacks when compared to the MPLS based techniques. It's advantages, in theory, are that deployment should be simpler because there is no requirement for MPLS and it can be seen as a true end-to-end service exactly because it relies on IP tunnelling which is a well known and proven technology. It has disadvantages when compared to the MPLS techniques because the end users in different domains are limited to use Cisco equipment (as the solution is currently Cisco proprietary) with a specific IOS version. In addition, to run on Cisco's higher-end routers specialised hardware (Tunnel interface) is required to originate or terminate the end points of the UTI. It is, however, suggested to evaluate further this technology.

Future work also needs to be focused on following the developments in the optical transmission technology. It has already been outlined that solutions such as Lambda Unite from Lucent are of particular interest and potential. Alternative solutions from other equipment vendors should also be investigated. In DANTE has in place provision for joint development activities in its contracts with the three providers of wavelength connectivity for GÉANT which would provide a suitable framework in which to carry out such investigations.

ACRONYMS

APM	Access Port Managers
ATM	Asynchronous Transfer Mode
ATOM	Any Transport Over MPLS
CCC	Circuit Cross Connect
CLI	Command Line Interface
DBR	Deterministic Bit Rate
DWDM	Dense Wave Division Multiplexing
GE	Gigabit Ethernet
G-MPLS	Generalised Multi Protocol Label Switching
GNM	Group Network Manager
IP	Internet Protocol
IPv6	Internet Protocol version 6
MBS	Managed Bandwidth Service
MPLS	Multi Protocol Label Switching
NOC	Network Operations Centre
NREN	National Research and Education Network
PHB	Per Hop Behaviour
POS	Packet Over Sonet
PVC	Permanent Virtual Connection
QoS	Quality of Service
SBR	Statistical Bit Rate
SDH	Synchronous Digital Hierarchy
SVC	Switched Virtual Connection
UNI	User-Network Interface
VCC	Virtual Channel Connection
VPC	Virtual Path Connection
VPN	Virtual Private Network

REFERENCES

[GEA-D9.1]   *Specification and Implementation Plan for a Premium IP Service*
                  M. Campanella et al. – 9 April 2001

[MBS]   *The TEN-155 Managed Bandwidth Service*
                  http://www.dante.net/mbs

[SEQUIN]   *The SEQUIN project,*
                  http://www.dante.net/sequin

[SEQD2.1]   *Quality of Service Definition*
                  M. Campanella et al – 31 March 2001

[