02.10.07

Deliverable DJ4.1.2: Report on GÉANT2 Testbed Usage

Deliverable DJ4.1.2

Contractual Date:	31/08/07
Actual Date:	02/10/07
Contract Number:	511082
Instrument type:	Integrated Infrastructure Initiative (I3)
Activity:	JRA4
Work Item:	WI1 Distributed testbed in support for other activities and other FP6 Projects
Nature of Deliverable:	R
Dissemination Level	PU
Lead Partner	DANTE
Document Code	GN2-07-226v4

Authors: Guy Roberts (DANTE), Michael Enrico (DANTE)

Abstract

This deliverable describes the usage of the GÉANT2 testbed that has been constructed and is being operated under work item 1 of JRA4, during its first months of operation. Three user groups have successfully made use of the testbed: GN2 JRA3 for its first live BoD demonstration, the FP6 EXPReS project for the evaluation of network layer performance of sub-10Gbps lightpaths and DANTE engineers for vendor interoperability testing of so-called "next generation SDH". Plans for extensive GMPLS testing (to be done as part of the GN2 JRA4 WI-02 "technology testing" programme) are currently under development.

Table of Contents

0 Executive Summary iv

1 Testbed overview 1

2 JRA3/AutoBAHN live BoD demonstration 3
2.1 Overview 3
2.2 Demonstration circuit 4
2.3 Testing scenario 5
2.4 AutoBAHN demonstration outcomes 7

3 Lightpath-based TCP/UDP flow evaluation for the EXPReS project 8
3.1 EXPReS 8
3.2 UDP and TCP flows over NG-SDH paths 9
3.3 Test activities 9
3.3.1 Characterisation of an EPL circuit with UDP flows 9
3.3.2 Characterisation of an EPL circuit with TCP flows 10
3.4 Test results 11
3.4.1 UDP testing 11
3.4.2 TCP/IP testing 12
3.5 UDP/TCP flow testing outcomes 13

4 NG-SDH vendor interoperability testing 15
4.1 Interoperability testing overview 15

5 Miscellaneous and future use of the testbed 16
5.1 Future use of the testbed 16

6 Conclusions 18

Project: GN2
Deliverable Number: DJ4.1.2
Date of Issue: 02/10/07
EC Contract No.: 511082
Document Code: GN2-07-226v4

7 References 19

8 Acronyms 20

Table of Figures

Figure 1.1: GÉANT2 Testbed 2
Figure 2.1: AutoBAHN demonstration overview 4
Figure 2.2: Testbed usage for demonstrating live circuit creation using AutoBAHN 5
Figure 2.3: Reservation request in AutoBAHN 6
Figure 2.4: Visualisation of a circuit reservation AutoBAHN 7
Figure 3.1: UDP throughput on 4Gbit/s testbed circuit 12
Figure 3.2: UDP latency results on 4Gbit/s testbed circuit 12
Figure 3.3: TCP/IP interaction with EPL paths. 13

0 Executive Summary

With the exception of two wavelengths, the construction of the GÉANT2 distributed testbed was completed by May 2007. By this time, even though it had just been handed over by Alcatel, the testbed was already in great demand.

The testbed Network Management System (NMS) has proven to be an invaluable asset for the development of a prototype JRA3/AutoBAHN domain manager (DM) for GÉANT2. Using 1359 ISN northbound interface (for the purpose of dynamic provisioning of circuits), it was particularly instrumental in helping to meet the significant milestone for JRA3 (demonstrating a prototype of the JRA3/AutoBAHN system that automatically provisioned an "on-demand" GE service that traversed multiple domains during the 4th GÉANT2 technical workshop in June). Without the testbed, it would not have been possible to develop this DM code against the ISN northbound interface to the production NMS. Successful completion of this objective was only made possible by the use of the testbed.

The testbed was also used to provide the FABRIC (JRA) activity of the EXPReS project with a 3000km long 4Gbps Ethernet private line (EPL) service between two 10GE interfaces on the testbed MCC in London. This was set up within one week, including the installation of the 10GE-capable workstations in the London POP, in time for initial test results to be presented during TNC 2007. Test results from this work have highlighted interactions between TCP flow control and the EPL paths provided by Alcatel's SDH cross-connect equipment.

Finally, the testbed is being used for multi-vendor interoperability testing of next-generation SDH features although the initial results of this work are not included in this public deliverable as they are currently the subject of discussions being held between those that have performed the work and their respective equipment suppliers.

In addition to these three "headline" applications, the testbed has also been used for numerous routine "operational model" type applications that, although appearing at first sight to be more mundane than the main applications described herein, are nevertheless very valuable to those operating the GÉANT2 switching platform. These are described further in section 5.

In summary, in the four months that the testbed has been available to the GÉANT2 community, important technology testing activities have been made possible. In the next year, it is expected that the testbed will be used for GMPLS technology evaluation (as part of the GN2 JRA4 WI-02 "technology testing" programme).

1 Testbed overview

The design of the GÉANT2 distributed testbed is described in deliverable DJ4.1.1: “Report on Design and Implementation of Testbed and Operational Procedures”. The testbed is basically comprised of five Alcatel 1678MCC next-generation SDH cross-connects. These are located in the GÉANT2 PoPs, as shown in Figure 1.1. Connectivity between the cross-connects is provided using STM-64 wavelengths from the GÉANT2 production network. Reflecting their usage in GÉANT2, the MCC equipment at these sites uses a VC-3/4 based cross-connection core and supports STM-64, GE and 10GE interfaces[4].

The timeline for the installation and commissioning of the testbed was as follows:

- The 1678 MCC cross-connects in London, Amsterdam, Frankfurt and Prague were installed by February.
- Prague-Frankfurt, Paris-Prague, Frankfurt-Amsterdam and London-Paris wavelengths were installed by March.
- The last cross-connect to be commissioned was in Paris in April (the installation had been done earlier but there were delays in the provision of the necessary DC power).
- The first use of the (incomplete) testbed occurred in May to test the Alcatel 1359 ISN interface (a northbound interface to the NMS) in preparation for the JRA3/AutoBAHN demo.
- The last two wavelengths: London-Paris and London-Frankfurt became available in June.

[4] Other interfaces (such as STM-16 and smaller) are possible, but will only be fitted if and when justifiable needs arise.

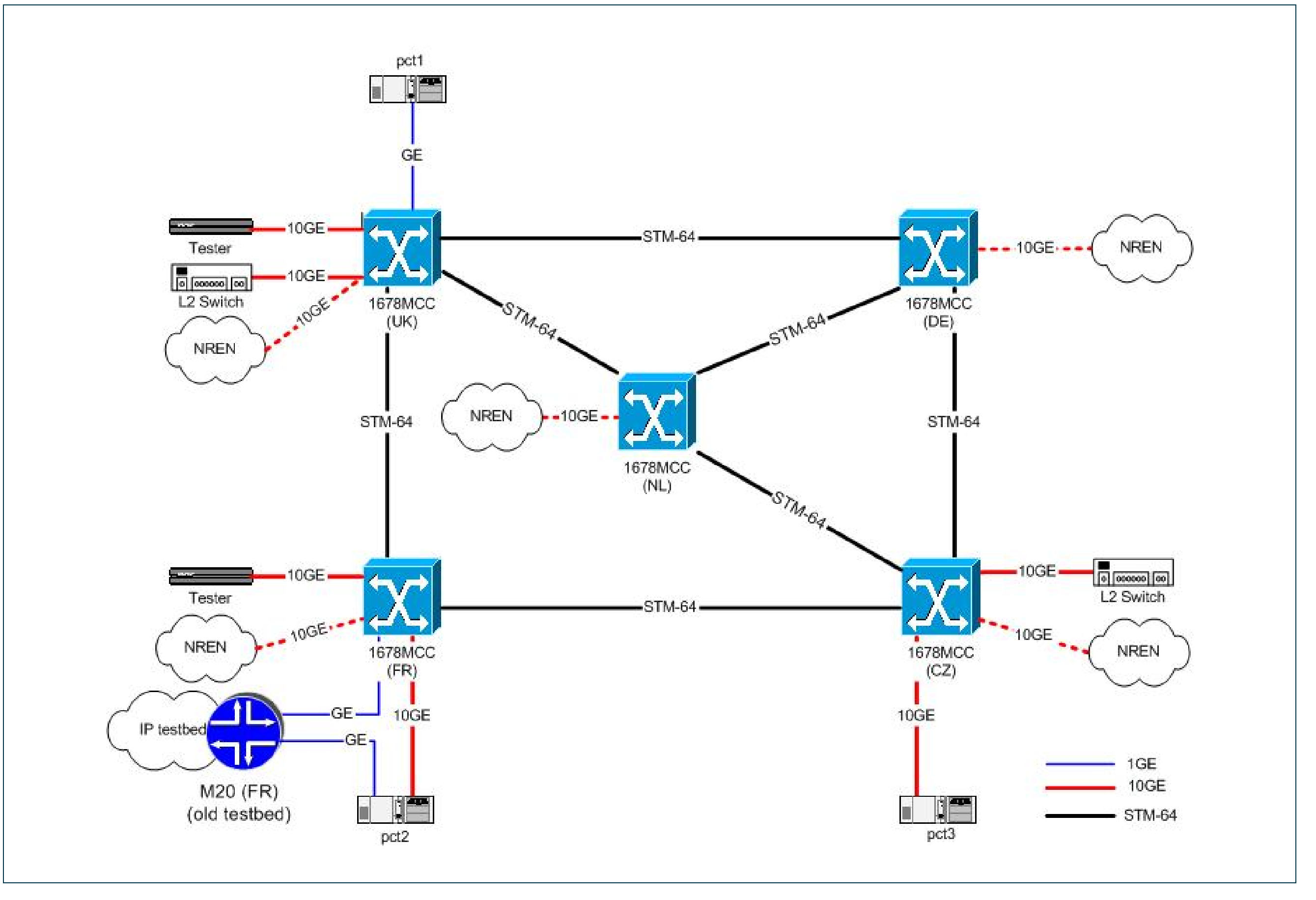

Figure 1.1: GÉANT2 Testbed

2 JRA3/AutoBAHN live BoD demonstration

2.1 Overview

The GN2-JRA3 research activity focuses on the investigation and development of an end-to-end (and therefore multi-domain) “Bandwidth Allocation and Reservation Service”; in other words a “Bandwidth on Demand” ('BoD') service. Sometimes the term “circuit-based” has been used in order to highlight the fact that the bandwidth should be reserved, not contended, exhibit some form of deterministic performance, and be logically separated from other traffic sharing the network. A number of end-to-end services fulfil these criteria, including: Point-to-point Ethernet (“Ethernet private lines” or EPLs), Point-to-point SONET/SDH (the equivalent of carrier IPLCs) and point-to-point “wavelengths” (for example, based on G.709 ODUk switching or all-optical switching of regenerated wavelengths).

On the 05 June 2007, a live demonstration of a BoD circuit being created using AutoBAHN was presented to the GÉANT2 APMs. The aim of this demonstration was to exhibit the inter-domain functionality of the AutoBAHN system by using it to reserve and implement a circuit across three domains and between two hosts. The domains participating in this demonstration were HEAnet, GÉANT2 and GRNET. These three domains use three different transmission technologies: In GÉANT2, Alcatel SDH cross-connect equipment is used to provide EPL circuits; in HEAnet, an Ethernet service is provided by MPLS over Ethernet; in GRNET layer-2 label switched paths (LSPs) are provisioned on routers.

An overview of the demonstration connectivity is shown in Figure 2.1:

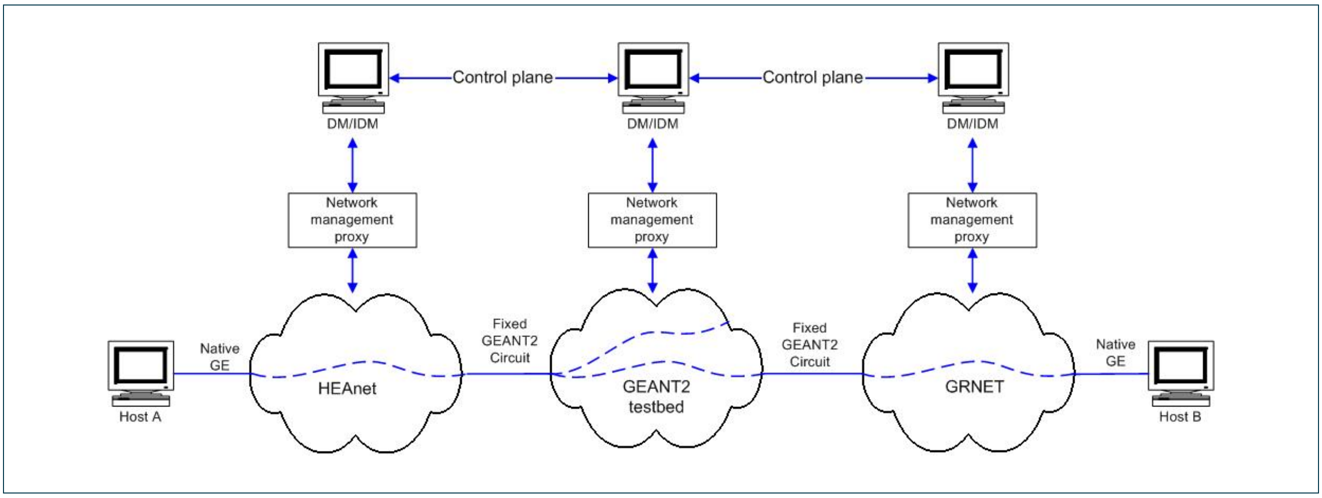

Figure 2.1: AutoBAHN demonstration overview

Each domain runs one instance of the AutoBAHN Inter-Domain Manager (IDM). These are located on a server in each domain. The IDM communicates to the network management system in each domain via a network management (NM) proxy. The IDM to NM proxy interface is implemented using a standardised web services interface. This interface supports discovery of the domain's network architecture and topology. It also supports request and confirmation messages for circuit creation within each domain.

2.2 Demonstration circuit

On-demand creation of a Gigabit Ethernet circuit was demonstrated between a host located in Dublin and a second host in Crete. The circuit transited three networks: Native Ethernet in HEAnet, NG-SDH in GÉANT2 and an MPLS layer-2 VPN in GRNET.

Figure 2.2 shows an overview of the end-to-end connectivity of circuit, emphasising details within the GÉANT2 domain. Two VC-4-7v trails were requested by the AutoBAHN IDM via a machine interface to the Alcatel NMS (the aforementioned 1359 ISN). These circuits were implemented in the testbed as dynamic VC-4-7v trails, and both were routed by the Alcatel network management system from London to Paris via Prague and Amsterdam. (this was the only path available at the time due because the testbed was not quite complete, as explained above).

Two static circuits were used to connect the testbed to the other networks participating in the demonstration. The interconnections between the testbed and the GÉANT2 production network were 1000baseSX (physical Ethernet) in Paris and STM 64 in London. Since the currently available release of the ISN interface used to dynamically provision trails will only provide connections between GE ports (and not 10GE ports), a loop in London provided a termination point for the dynamic link and the static link to Athens.

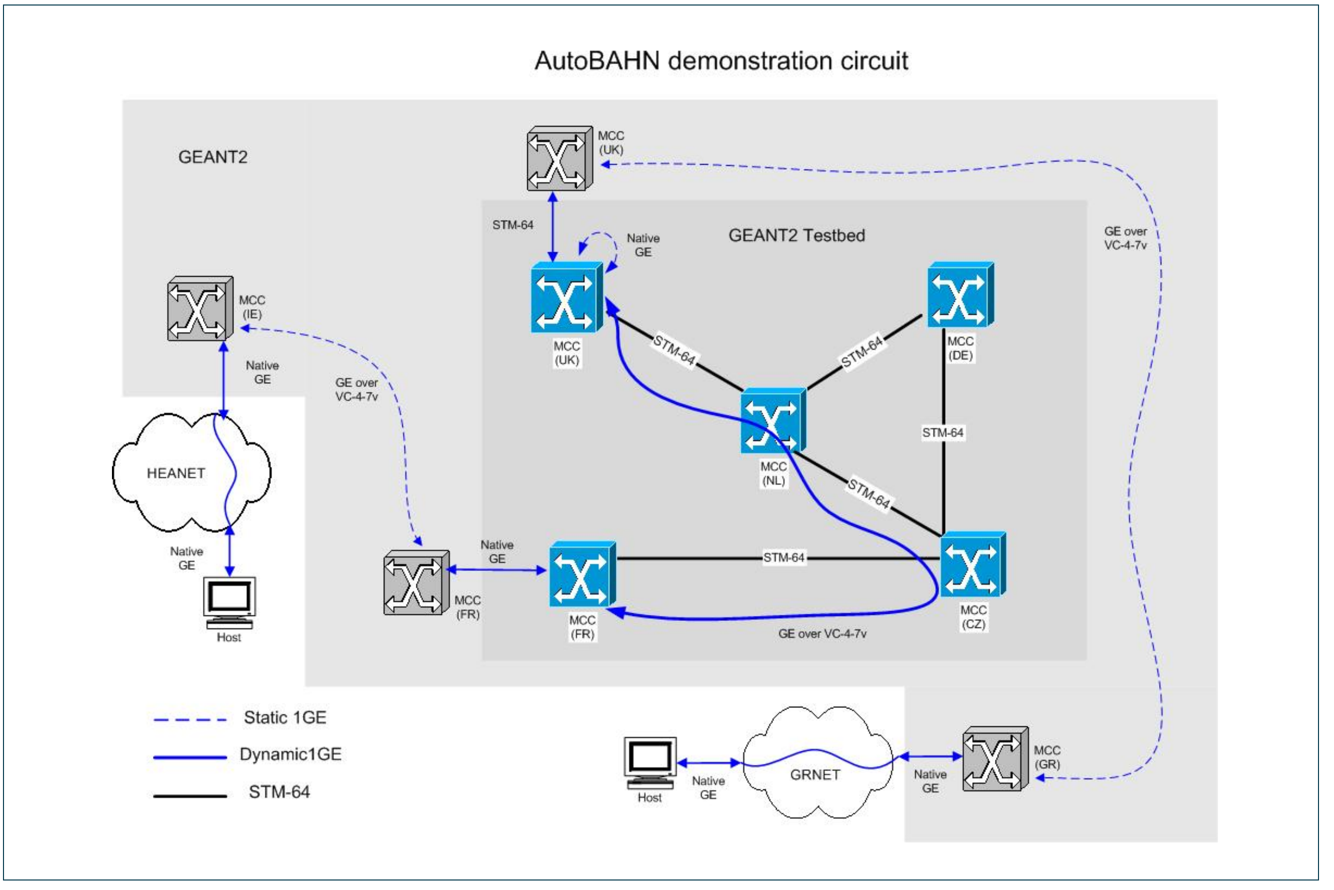

Figure 2.2: Testbed usage for demonstrating live circuit creation using AutoBAHN

2.3 Testing scenario

To confirm the correct operation of the on-demand circuit creation, the following test scenarios were performed.

1. User enters a reservation request to build a path from HEAnet to GRNET.
2. IDM performs an inter-domain pathfinding computation.
3. The IDM performs a checkResources operation in each domain and gets a “good” response.
4. The IDM performs a reserveResources/addReservation operation in each domain.
5. The IDM performs a removeResources operation in each domain.

A second reservation attempt, sharing a link on the GÉANT2 testbed with the first reservation at an overlapping time period, was rejected due to lack of capacity.

Figure 2.3 shows the process for requesting a circuit using the AutoBAHN user interface. The start and end port of the circuit are nominated, as well as the start time and capacity. Figure 2.4 shows the successfully completed circuit reservation. The transmission path was confirmed for this circuit by streaming a video over the path.

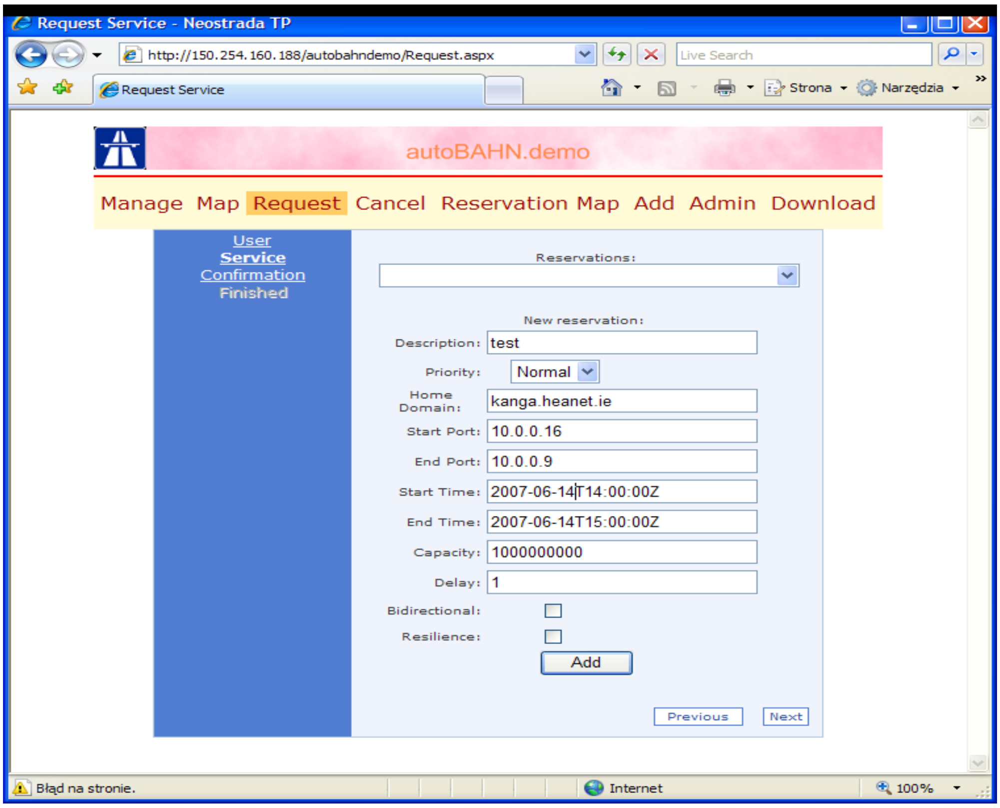

Figure 2.3: Reservation request in AutoBAHN

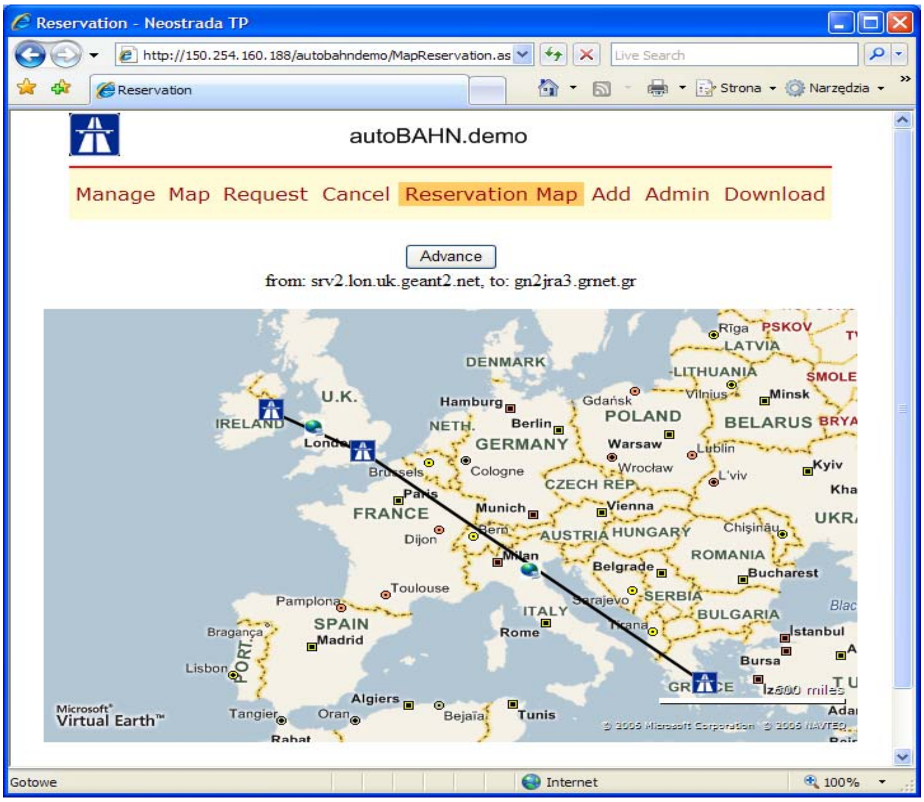

Figure 2.4: Visualisation of a circuit reservation AutoBAHN

2.4 AutoBAHN demonstration outcomes

Following the successful first demonstration of a live on-demand circuit provisioning, a press release was issued:

"Cambridge, UK, 11 July 2007: A major milestone has been accomplished by the European National Research and Education Networks (NRENs), where for the first time a user-requested high speed circuit has been set up dynamically between Ireland and Greece. This concept, known as "Bandwidth-on-Demand" allows users to request network capacity according to their needs.

The recent demonstration involved the dynamic establishment of a dedicated end-to-end 1 Gigabit Ethernet circuit between two end-user workstations. The circuit was set up within minutes and spanned the infrastructure of GRNET, the Greek NREN, the pan-European network GÉANT2, and the Irish NREN, HEAnet. In the trial, two workstations were interconnected through the circuit offering a data transmission speed one thousand times faster than a commercial 1 Mbps ASDL line for the transmission of high-resolution video. The circuit was also released in a dynamic manner."

This work would not have been possible without access to the testbed. This has been a successful result for JRA3, JRA4 and GÉANT2.

3 Lightpath-based TCP/UDP flow evaluation for the EXPReS project

3.1 EXPReS

Using high-speed communication networks, the FP6 EXPReS project plans to create a distributed, large-scale astronomical instrument of continental and inter-continental dimensions. This Very Long Baseline Interferometer (VLBI) will operate in real-time and connect some of the largest and most sensitive radio telescopes on the planet.

The overall objective of EXPReS is to create a production-level, real-time, electronic VLBI (or e-VLBI) service in which the radio telescopes are reliably connected to the central supercomputer at JIVE in the Netherlands via a high-speed optical-fibre communication network. With an aggregate data flow of up to 16 Gbps into JIVE, the EXPReS project aims to create a unique e-VLBI infrastructure that is open to the international scientific community, one in which access is based solely on scientific merit.

The e-VLBI (Very Long Baseline Interferometry) community is routinely transferring real-time data at 256Mbit/s, and many European telescopes can now sustain 512 Mbit/s transfers. A new generation correlator will be present at Jodrell Bank Observatory in 2008 to process wide-band data from the UK e-Merlin telescopes. Part of the EXPReS project is to link observations using the Onsala telescope in Sweden to this facility using lightpaths provisioned at 4Gbit/s. The ability, in the near future, to send data at 4Gbit/s from several European telescopes will improve the imaging ability of the whole array, allowing high angular resolution observations and also give unprecedented sensitivity for VLBI observations. This will enable new scientific research to be carried out that previously could not be managed.

The connectivity for this project will, in part, be supplied by GÉANT2. In preparation for this work, the EXPReS project researchers performed throughput trials on the GÉANT2 network. This work was requested, at short notice, to be carried out in May and June 2007. In order to ensure rapid deployment of these tests, with minimal impact on GÉANT2's production network, these tests were performed on the GÉANT2 testbed.

3.2 UDP and TCP flows over NG-SDH paths

The transmission flow testing was a collaborative effort between members of the FABRIC Joint Research Activity of the EXPReS project, and DANTE. The purpose of these ongoing tests was to demonstrate and characterise multi-gigabit data flows over GÉANT2 lightpaths using UDP and TCP transport protocols. Of particular interest in these tests was to characterise the stability of the UDP flows, and the behaviour of bursts in the TCP traffic when carried over a lightpath provisioned with a fixed bandwidth capacity.

The following topics were investigated (and are still being researched at the time of writing):

- Understand the behaviour of multi-gigabit UDP flows over GÉANT2 lightpaths.
- Demonstrate high performance UDP/IP data flows similar to those to be used in moving data in the real-time environment e-VLBI. Throughput, latency, packet loss and stability are all important in this application.
- Analysis of TCP performance at multi-gigabit speeds.
- Analysis of TCP performance when there are transient bursts that exceed the provisioned bandwidth of the lightpath.
- Understand how the GÉANT2 high speed infrastructures reacts to load fluctuations – e.g. how does latency and jitter change with the load on the network?
- Understand how the network responds to bursty TCP flows, in particular gain understanding of queue behaviour in the lightpath equipment.

3.3 Test activities

In this section, details of the each of the tests required are discussed. The work described here has been performed collaboratively between DANTE engineering staff and members of the EXPReS project.

3.3.1 Characterisation of an EPL circuit with UDP flows

These tests use high performance PCs with server quality motherboards and 10 gigabit Ethernet interfaces to determine the performance of the lightpath using UDP traffic. The servers have previously been demonstrated to support memory-memory transfers between back-to-back PCs of 9.4 Gbit/s.

The following sections describe the Network Characteristics under study.

Latency and Packet Jitter

The round trip times are measured as a function of the message size sent using a simple request-response application protocol. Measurements are made with UDP/IP using the “UDPmon” network tool. Typically 100000 singleton measurements can be made for about 1000 message sizes.

Measurements were made of round-trip latency versus packet size (packet size from 1000 to 9000 bytes) and latency histograms were recorded for packet sizes of 1000, 1472, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 8972 bytes.

Throughput

Tests are also made using streams of UDP and IP packets with carefully controlled packet spacing to determine as a function of the packet spacing:

- End-to-end capacity.
- Achievable UDP throughput.
- Packet loss.
- Packet re-ordering.

This information is intended to assist in the understanding of the TCP stack performance.

Measurements were made of capacity, achievable throughput and loss versus packet spacing (0-40 µs in steps of 1 µs for a set of packet sizes of 1000, 1472, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 8972 bytes).

Packet loss frequency and loss pattern

In case of non-null packet loss, the analysis of the packet loss pattern is important to check if packets are lost randomly and individually, or in groups of continuous packets. The former case is usually an indication of temporary congestion, while the latter is a symptom of bandwidth restrictions or low tolerance of network devices to burstiness produced by individual streams.

Packet loss frequencies and patterns will be measured using controlled streams of UDP packets. This complementary information will assist in the analysis of the TCP behaviour.

If required, checks will be made to determine where the losses occur using:

- Statistics from the Alcatel switches.
- Data from the end host stacks.

One way delay estimates

Relative 1-way delays will be measured using UDPmon to transmit carefully spaced UDP packets.

3.3.2 Characterisation of an EPL circuit with TCP flows

The server quality PCs are used to measure the memory-to-memory TCP achievable throughput using Iperf and other memory-memory TCP test programs to determine:

- Behaviour of TCP flows over Euro-scale distances (RTTs) on lightpaths with different levels of provisioned bandwidth.
- What TCP achievable throughput can be achieved with good connectivity.
- Where the losses are most likely to occur.

web100 in the 2.6.20-web100_pktd-plus Linux operating system kernel is used to record the behaviour of the TCP protocol and tcpdump is also run in the end hosts to investigate packet dynamics.

Sensible choices of parameters, such as Txquelen and interrupt coalescence, were determined from recent ESLEA tests and Laboratory work.

The following measurements were made:

- Time series throughput of the TCP stream(s).
- Behaviour of the TCP parameters as a function of time.
- Throughput versus TCP buffer size.
- CPU loads on transmitter and receiver.
- The behaviour of the currently available TCP stacks at multi-gigabit speeds using different values of RTT.

3.4 Test results

3.4.1 UDP testing

Figure 3.1 shows the UDP throughput as Mbit/s through the 4Gbit/s test path created on the GÉANT2 testbed. These results show that for frame sizes of 1472 bytes and above, a throughput in excess of 4 Gbit/s is achievable. This result demonstrates a good throughput performance for UDP transmission over the Alcatel EPL path.

Figure 3.2 shows the UDP latency results for the test path. A stable one-way delay of 23.435 µs is measured.

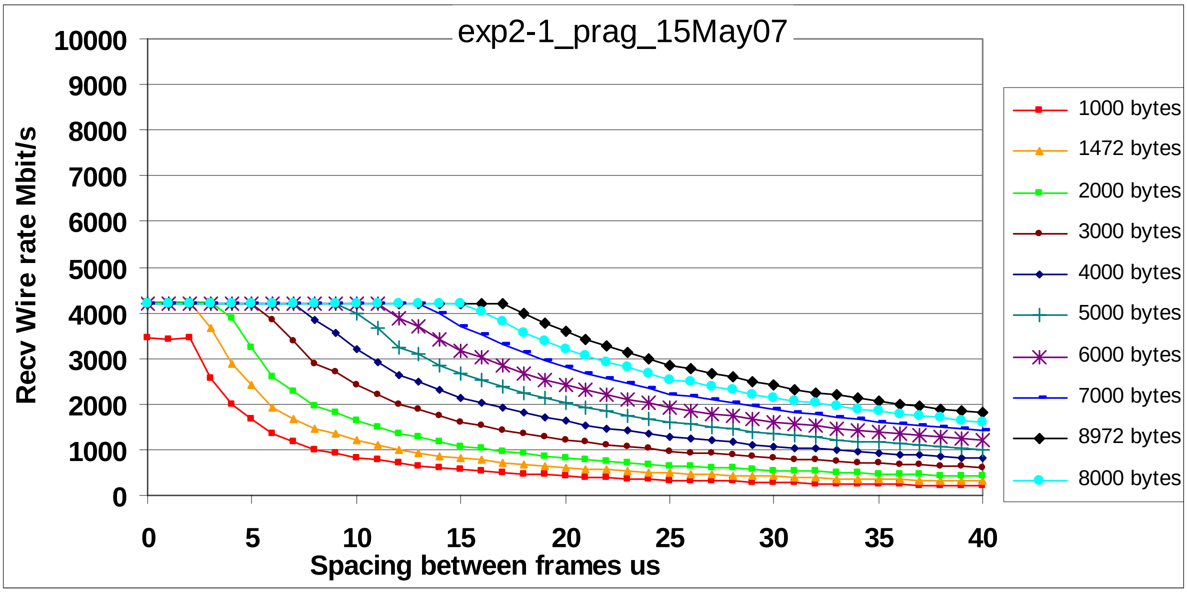

Figure 3.1: UDP throughput on 4Gbit/s testbed circuit

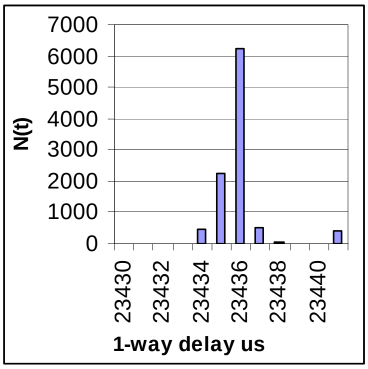

Figure 3.2: UDP latency results on 4Gbit/s testbed circuit

Jitter testing and UDP flow stability tests showed negligible impact of the EPL circuit on performance. In summary, UDP flows were shown to perform well over the testbed circuit, with little or no degradation of the flow beyond the unavoidable latency associated with the transmission path.

3.4.2 TCP/IP testing

Testing of TCP/IP performance over the EPL paths is ongoing. However, initial tests have highlighted a known performance problem with EPL circuits terminating on 10 gigabit Ethernet interfaces. The nature of this interaction is described next.

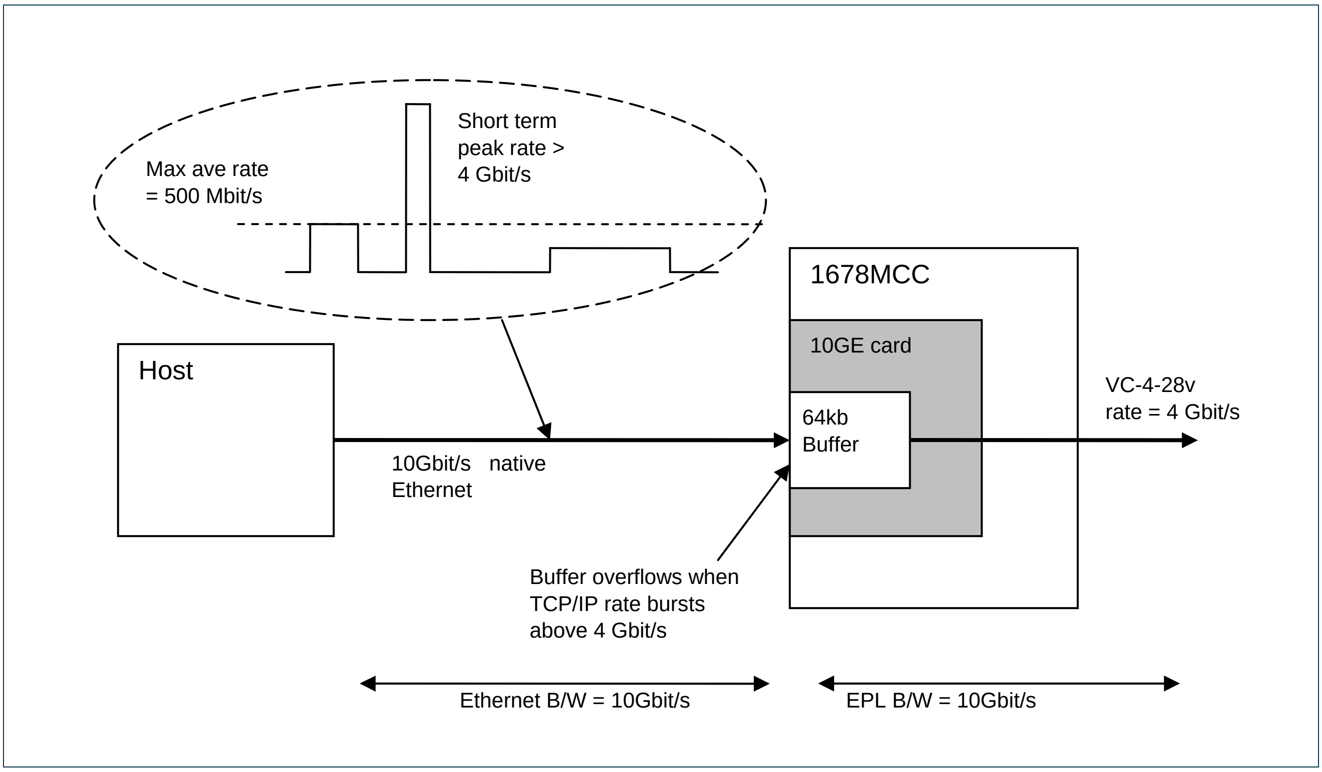

Figure 3.3: TCP/IP interaction with EPL paths.

The schematic in Figure 3.3 depicts how a TCP/IP host connects via native 10 gigabit Ethernet to an EPL circuit in the Alcatel 1678MCC equipment. Since the host has no knowledge of the capacity of the transmission channel, the TCP adjusts its flow rate at the host to match the bandwidth of the transmission channel. This is done by ramping up the throughput according to a standard algorithm; when packet losses are detected, the TCP backs off the throughput. Unfortunately, in real networks it is not often easy to prevent the host generating “bursty” traffic on a 10 gigabit Ethernet interface (as illustrated in Figure 3.3). The result is that the 64kbyte buffer on the 10GE card can overflow during bursts above the transmission channel bandwidth. The TCP flow control algorithm interprets these packet drops in the buffer as insufficient transmission bandwidth and can back off the flow rate too far.

Testing is ongoing to characterise the impact of this buffer size on GÉANT2 EPL circuit customers.

3.5 UDP/TCP flow testing outcomes

This collaboration, involving demonstrating and measuring the performance of multi-gigabit flows over the lightpath development network, has provided and will continue to provide useful experience and benefits to DANTE in the operation of the GÉANT2 production network services. These results may also be directly applicable to the networks operated by the NRENs and current Grid projects.

One final point that can be highlighted is that it was possible to set up this experiment within a few days (with very little advance notice), and in time to facilitate the presentation of "hot-off-the-press" results at the TERENA networking conference (TNC 2007) in Denmark in May 2007 during a presentation given by Richard Hughes-Jones of the University of Manchester and the EXPReS project [RHJ2007].

4 NG-SDH vendor interoperability testing

4.1 Interoperability testing overview

This section describes the interoperability tests of Ethernet over an Ethernet Private Line (EPL) circuit between the Alcatel 1678MCC equipment and the Ciena CoreDirector equipment. These tests have been performed as a collaboration between Internet2 and DANTE during June, July and August 2007. The purpose of these tests is to confirm the compatibility of the two vendors' implementations of EPL paths using the approach of framed-based Generic Framing Procedure (GFP-F) over virtually concatenated VC-4/STS-3c SDH/SONET trails. Tests have been performed between both gigabit and 10 Gigabit Ethernet ports.

While these tests have been performed to ensure that transatlantic point-to-point circuits can be implemented, the test results are likely to also be useful for connectivity to other members of the GN2 community; Ciena equipment is also used by ja.net (the UK NREN operator) and Internet2.

On the whole, compatibility was demonstrated except that there were a few early indications of several compatibility issues. These are being reviewed in conjunction with Alcatel and Ciena and therefore the *details of this work are omitted from the public version of this deliverable for the time being*. This document may be re-issued with more details of these test results at a later date after the consultation with the suppliers has been completed.

5 Miscellaneous and future use of the testbed

The previous sections outline three "headline" activities that have been facilitated by the testbed. In addition to these, there have been numerous occasions when DANTE engineers have been able to make use of the testbed to test previously untried configuration operations (before instructing the GÉANT2 NOC to do so on the production network).

One recent example has been the testing of the provisioning of 1+1 protected EPL service instances based on invoking SDH's sub-network connection protection (SNCP) of the individual VC-4 trails that comprise the underlying virtual concatenation group.

The testbed has also proved to be invaluable for familiarisation of Alcatel equipment (and its management system) by those DANTE and NOC staff with no Alcatel experience. This has been useful both in advance of and following formalised training programmes operated by the supplier. Additionally, it allows DANTE to request bespoke "hands-on" training from the supplier, which can be undertaken at DANTE's offices (remote access to equipment in supplier facilities has proved to be difficult in the past). An upcoming example of this (at the time of writing) is a bespoke training/workshop on the 1359 ISN northbound interface to the Alcatel NMS.

These non-headline activities are essentially using the testbed as an "operational network model" (it is common practice amongst large network operators to maintain such reference models). These are also used to test software upgrades before committing them to the network elements on the production network, even after they have undergone the thorough regression testing that would be expected of any supplier. This will also be done for GÉANT2 prior to the next upgrade of the 1678 MCC software from the currently installed release 4.1 to 4.2 (or possibly straight to 4.3), which is expected to take place within the next few months.

5.1 Future use of the testbed

The next headline use of the testbed will be the testing Alcatel's implementation of GMPLS control-plane software. Although a precursor to such testing was previously undertaken by DANTE engineers in Alcatel facilities, this was carried two years ago and the software has developed since then. In addition, some of the non-generally available features are to be investigated, most notably the beta implementation of the OIF UNI2.0

as per the 2005 draft implementation agreement. Such “bleeding edge” activities are simply too risky to be undertaken on the production network. This work is described at a relatively high level in DJ4.2.1 [DJ421] and a more detailed project plan is currently in production (the latter being drawn up in collaboration with the relevant Alcatel experts). The work will be undertaken during project year 4.

6 Conclusions

The GÉANT2 distributed testbed has proved to be an invaluable resource for many that are directly and indirectly involved with GÉANT2 and its associated research and service activities. The “headline” examples that have been quoted in this report are as follows:

- Access to the testbed NMS (and, more precisely, the 1359 ISN northbound interface) facilitating the development of a prototype JRA3/AutoBAHN domain manager (DM) for GÉANT2 for the purpose of dynamic provisioning of circuits. This was particularly important since there was a significant milestone for JRA3; to demonstrate, during the 4th GÉANT2 technical workshop (in June), a prototype of the JRA3/AutoBAHN system automatically provisioning an “on-demand” GE service traversing multiple domains. It would not have been possible to develop this DM code against the ISN northbound interface to the production NMS. Successful completion of the AutoBAHN demonstration was made possible by use of the testbed.
- The provision of a 3000km long 4Gbps Ethernet private line (EPL) service between two 10GE client interfaces for the FABRIC (JRA) activity of the EXPReS project. This was set up within one week, including the installation of the 10GE-capable workstations in the London POP, in time for initial test results to be presented during TNC 2007. Test results from this work have highlighted interactions between TCP flow control and the EPL paths provided by Alcatel’s SDH cross-connect equipment.
- Multi-vendor interoperability testing of next-generation SDH features.

In addition to these, numerous other “miscellaneous” uses have been made of the testbed, most of these relating to the “operational network model” aspect that was always anticipated as being one of the facets of the overall remit of the testbed.

In the four months that the testbed has been available to the GÉANT2 community, important technology testing activities have been made possible an in the next year DANTE expects to make use of the testbed for GMPLS technology evaluation (as part of the GN2 JRA4 WI-02 “technology testing” programme).

7 References

[RHJ2007] http://tnc2007.terena.org/programme/presentations/show.php?pres_id=100

[DJ421] http://intranet.geant2.net/server/show/conMediaFile.6911

8 Acronyms

APM	Access Port Manager (network operations point of contact between an NREN and DANTE operations)
AutoBAHN	GN2 bandwidth on demand system
BoD	Bandwidth on Demand
CZ	Czech Republic
DCN	Data Communications Network – management network in SDH
DE	Germany
E-NNI	External Network-to-Network Interface
EXPReS	Express Production Real-time e-VLBI Service
EPL	Ethernet Private Line
EVPL	Ethernet Virtual Private Line
FP6	Framework Programme 6
FR	France
GFP	Generic Framing Protocol
GRNET	Greek NREN
GN2	GÉANT2 project
GMPLS	Generalised Multiprotocol Label Switching
GUI	Graphical User Interface
HEAnet	Irish NREN
IDM	Inter-Domain Manager for AutoBAHN system
IP	Internet Protocol
ISN	Alcatel proprietary open services interface for multi-service/multi-technology networks
JRA3	Joint Research Activity 3 (encompasses the bandwidth on demand project now known as autobahn)
JRA4	Joint Research Activity 4 (includes several testing activities including testbed development and cross border fibre)
LM	Light Manager – Alcatel's WDM equipment
MCC	Metro Core Connect – Alcatel's SDH cross-connect product
NE	Network Element
NIC	Network Interface Card
NL	Netherlands
NOC	Network Operations Centre
NM	Network Manager – Alcatel 1353 NM element management tool
NMS	Network Management System

NNI	Network-to-Network Interface
NREN	National Research and Education Network
OIF	Optical Internetworking Forum
OSI	Open Systems Interconnection
OSPF	Open Shortest Path First
PoP	Point of Presence
RM	Regional Manager – Alcatel network management tool
RTT	Return Trip Time
SDH	Synchronous Digital Hierarchy
SNCP	Sub-network connection protection – SDH protection mechanism
STM	Synchronous Transfer Module – SDH frame format
TCP	Transmission Control Protocol
TNC	Terena Networking Conference
UDP	User Datagram Protocol
VCG	Virtual concatenation group
VLAN	Virtual Local Area Network
VLBI	Very Long Baseline Interferometer
XFP	10 GE small form factor pluggable optical transceiver