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Deliverable DS1.3.2,4: Annual Advanced Services Usage Report

Deliverable DS1.3.2,4

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Authors:	E. Apted (DANTE)

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Abstract

This deliverable reports on the take-up and usage of GÉANT's advanced services, GÉANT Plus and GÉANT Lambda, during Year 4 of the GN3 Project. It describes each service and provides figures for new point-to-point links delivered, the overall status of advanced services and an update on the End-to-End Coordination Unit (E2ECU) that has been supporting some end-to-end links.

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Executive Summary

GÉANT is a hybrid network, combining the operation of a shared Internet Protocol (IP) infrastructure with the ability to provide additional dedicated point-to-point links reserved exclusively for particular user groups. During 2012, this hybridisation has been taken to a new level, with the introduction of new, cutting-edge equipment.

GÉANT's point-to-point services, GÉANT Plus and GÉANT Lambda, benefit from the latest developments in technology and the telecommunications market to meet an ever-growing demand from the user community, not only for a high-capacity network, but also for guaranteed availability and performance. The GÉANT Plus service, now using Multi-Protocol Label Switching (MPLS) technology, flexibly offers capacity up to 10 Gbps, whilst GÉANT Lambda offers dedicated, guaranteed network capacity at 10 Gbps or 100 Gbps. These services provide capacity between the user groups concerned, ensuring reliable, secure, high-bandwidth, end-to-end connectivity.

GÉANT Lambda circuits are offered between National Research and Education Networks (NRENs) in Europe where it has been possible to procure at an affordable price the necessary network infrastructure, i.e. dark (unlit) fibre optic cables on which circuits can be incrementally added as demand requires. GÉANT Plus is now available at all GÉANT Points of Presence, following the installation of the new Juniper MX-series routers.

A total of 5 new point-to-point circuits were delivered on the GÉANT infrastructure during Year 4. Of these, 4 were GÉANT Plus services implemented as Layer 2 circuits. The remaining circuit, for LHC, was the first 100 Gbps service that DANTE has ever provided, being a GÉANT Lambda between CERN in Geneva and their new hosting centre in Budapest. 7 GÉANT Plus services and 2 GÉANT Lambda services were cancelled during Year 4. The total number of GÉANT Plus and GÉANT Lambda links in use near the end of Year 4 is 65 (44 GÉANT Plus, 21 GÉANT Lambda). The FEDERICA and LHC projects have the most, with 13 circuits each, followed by DEISA / PRACE with 8 circuits. All the other projects use 4 or fewer circuits.

The Bandwidth on Demand service is proving to be increasingly popular with many of the NRENs currently involved and it is treated by the GÉANT NOC as a production service.

The End-to-End Coordination Unit (E2ECU) is currently in place to provide coordination and monitoring for a subset of these point-to-point circuits, namely, those for LHCOPN, DEISA and IGTMD. During Year 4, the E2ECU tracked the resolution of 349 incidents, such as connectivity problems, circuit monitoring faults and planned maintenance. The E2ECU function will cease at the end of February 2013. Those responsible for providing future multi-domain support will include the Multi-Domain Service Desk (MDSD).

Year 4 saw the successful production launch of the MDSD, which offers comprehensive one-stop-shop support to handle general queries for multi-domain services and technical assistance for multi-domain tools, such as perfSONAR and Bandwidth on Demand. It will play an increasingly important role in providing multi-domain circuit monitoring and support services.

Planned service developments for advanced services include the ongoing enhancement of the website for NREN partner users, the Partner Portal, to add content on all GÉANT services and to introduce a new GÉANT NREN Tools Gateway page, to provide an easy overview of and access to all GÉANT account management tools.

1 Introduction to Advanced Services

Benefiting from the latest developments in technology and the telecommunications market, the GÉANT network offers the European research and education community a unique range of opportunities for international collaboration. In addition to the standard service, known as GÉANT IP, which provides access to the shared European Internet Protocol (IP) research and academic network, advanced services are available, delivering international point-to-point network connections free from the constraints inherent in a shared, routed infrastructure. Foremost among the advanced services are GÉANT Plus and GÉANT Lambda. Each of these is described below. (A description of the standard service, GÉANT IP, is included to provide a context for the advanced services; the remainder of the deliverable is concerned with the advanced services only.)

1.1 Network Developments

During 2012, the hybrid nature of the GÉANT network has been taken to a new level with the introduction of new, cutting-edge equipment. The GÉANT Plus and Bandwidth on Demand services have been moved off the original Alcatel equipment onto brand-new Juniper MX-series routers. This new equipment operates in parallel to the existing T-series Juniper routers, which support the IP backbone and IP services. Likewise, the GÉANT Lambda service is being migrated from other Alcatel equipment onto new, state-of-the-art Infinera equipment, which is also designed to support a new set of dark fibres. Each new set of equipment allows greater flexibility in the way these services are delivered, as well as much shorter lead times in the case of GÉANT Lambda.

For a map of the GÉANT network, please see Appendix B on page 29. For a more detailed description of GÉANT's services, please see the Service Catalogue on the Partner Portal [PP_Services].

1.2 GÉANT IP Service

1.2.1 Overview

The standard service, known as GÉANT IP, provides access via the GÉANT network to the shared European Internet Protocol (IP) research and academic network. It offers a robust, high-bandwidth solution to the international connectivity requirements of the majority of academic users, allowing transit for IP traffic between European National Research and Education Networks (NRENs), and between European NRENs and

associated networks globally (such as Internet2 and ESnet). Part of the European research and education backbone, the GÉANT IP network is over-provisioned by design, to allow small-to-medium-sized traffic flows along an uncongested path. The IP service is resilient in the case of hardware failure or fibre cuts, and uses advanced routing equipment to ensure fast recovery from unexpected events.

GÉANT IP access is available to members of the GÉANT consortium at capacities of up to 40 Gbps (subject to technical and commercial considerations[1]) and is paid for by an annual subscription. Access can be given to non-consortium NRENs by special agreement.

1.2.2 Features

GÉANT IP provides the following features:

- A standard "best effort" IP service, i.e. with no bandwidth or performance guarantee between any communicating pair of addresses.
- Dual-stack (IPv4 and IPv6) core backbone based on packet-switching routers. The provision of IPv6 services means that GÉANT IP forms part of the world's first global next-generation Internet network.
- Multicast enabled, efficiently delivering data traffic in both one-to-many and many-to-many scenarios.
- Layer 2 Virtual Private Network (L2 VPN) facility, built on the common IP infrastructure yet appearing to the user as a dedicated protected circuit using Multi-Protocol Label Switching (MPLS) and including multi-domain VPNs. Delivery time is one week. There is no extra charge for GÉANT L2 VPN services.

  This service is currently offered in addition to the GÉANT Plus service, which is implemented in a similar way, but on a dedicated port, separate from that used by the IP Access.
- Backup protection against circuit failure at up to the full subscribed bandwidth on an appropriate interface is included in the standard IP subscription. Alternative dedicated backup capacity is available to those NRENs on the fibre cloud, as part of their GÉANT Plus subscription (see Section 1.3.1 below).
- IP peering. GÉANT offers NRENs the opportunity to exchange traffic with a carefully selected group of commercial organisations, such as Google and Microsoft. GÉANT peers selectively at Internet Exchanges in Amsterdam (AMS-IX), Frankfurt (DE-CIX) and Vienna (VIX).
- Physical interface types range from T3 (34 Mbps) to STM-64 or 10 GE (10 Gbps, or multiples thereof, subject to technical and commercial considerations).
- Setting up a new physical connection and IP Access from an NREN to the GÉANT IP network is a bespoke activity; delivery time will depend on NREN requirements.

1.3 Advanced Services

GÉANT offers two distinct classes of point-to-point services to NRENs who require dedicated international circuits for their users: GÉANT Plus and GÉANT Lambda. The principal benefits of each are identical: they offer

[1] Technical considerations include whether, where GÉANT does not have dark fibre, the local connectivity suppliers can provide such high bandwidth. The commercial considerations are primarily whether the NREN can afford the associated subscription and, occasionally, whether the project can afford the cross-subsidy.

reliable, secure, high-bandwidth, point-to-point connectivity between NRENs. A key advantage of the GÉANT Plus service is that, once an NREN has physically connected its equipment to the GÉANT equipment on a 10 Gbps port, each individual point-to-point service has a short set-up lead time and that several project connections can use the same port. The advantage of the GÉANT Lambda service is the use of dedicated ports connected using guaranteed bandwidth of 10 Gbps or 100 Gbps.

1.3.1 GÉANT Plus

1.3.1.1 *Overview*

The GÉANT Plus service allows NRENs to request point-to-point Layer 2 circuits across the GÉANT Juniper backbone. It provides a reliable, high-speed, secure, end-to-end service. GÉANT Plus is built on common infrastructure, but appears to its private users to be dedicated to that user's needs, thus combining the privacy and availability of a private circuit with the cost efficiency and robustness of a shared, managed infrastructure.

The service provides the NREN with up to 10 Gbps of pre-provisioned point-to-point capacity between the GÉANT Point of Presence (PoP) in its own country and their own equipment. Individual services can then be built in a straightforward manner between this port and a port at another GÉANT PoP that connects to another NREN or to a non-European international partner such as Internet2 or UbuntuNet. Because the capacity is provisioned in advance, circuits can be implemented or reconfigured at short notice and without incremental cost to the NREN (provided the NREN subscription or interface is not full; if it is full, a new interface can be ordered, at a cost to the NREN and with the appropriate lead time).

This capacity can be used to provide connections dedicated to individual research and education projects, particularly those with participants in multiple locations who wish to collaborate as if they were operating on the same local network.

The GÉANT Plus service is paid for by an annual subscription, which secures a 10 Gbps circuit capacity allocation to the NREN. Additional capacity and interfaces are available.

1.3.1.2 *Features*

GÉANT Plus provides the following features:

- Dedicated point-to-point circuits using Layer 2 MPLS technology configured over a network of new Juniper MX routers, which are connected via GÉANT's own Dense Wavelength-Division Multiplexing (DWDM) network as well as 10 Gbps leased trunks.
- Each NREN subscribing to the service is allocated 10 Gbps of circuit capacity (in addition to the IP connectivity), which may be used flexibly for different services to multiple locations.
- The 10 Gbps capacity allocation is fixed, regardless of the capacity of physical interfaces.
- Each NREN subscribing to the service is provided with access to the circuit on a single dedicated 10 Gigabit Ethernet (GE) or STM-64 interface on the GÉANT equipment at the national GÉANT PoP, as agreed by DANTE and the NREN.

- A circuit can be configured or reconfigured on the GÉANT Plus interface within five working days of receipt of request, assuming that sufficient capacity is available in the capacity allocations of both of the subscribing NRENs.
- Circuits may be configured for any specified service period.
- Circuits can be established between many European NRENs and from many European NRENs to a non-GÉANT organisation/destination, such as those behind Internet2, ESnet, CANARIE and USLHCnet. The transatlantic end-to-end (E2E) links use existing 10 Gbps circuits between New York and various points in Europe.
- A further 10 Gbps of capacity on a new interface can be provided at a fixed annual cost.
- Each GÉANT Plus connection can be limited to a specific bandwidth at the NREN's request.

1.3.1.3 *Availability*

GÉANT Plus is now available at all GÉANT Points of Presence (PoPs), following the installation of the new Juniper MX-series routers.

1.3.2 GÉANT Lambda

1.3.2.1 *Overview*

The GÉANT Lambda service provides private, transparent connections with 10 Gbps or 100 Gbps dedicated bandwidth between GÉANT NRENs. It is only available to NRENs connected to the GÉANT dark fibre cloud, as these connections are implemented on the GÉANT DWDM equipment.

The GÉANT Lambda service is paid for by an annual flat-rate fee for each connection deployed.

1.3.2.2 *Features*

GÉANT Lambda provides the following features:

- Transparent 10 Gbps connections between NREN-facing ports on GÉANT transmission equipment in GÉANT PoPs.
- Two standard interface types are available: 10 GE or 100 GE.
- Circuits can be configured with one of the following optics, specified at each NREN interface and provided by GÉANT: 10GBaseLR (1310 nm), 10GbaseER (1550 nm) or 100GBASE-LR4 (1310nm).
- If dissimilar interface types are required on each end of a single 10 Gbps circuit, this can be accommodated using the new GÉANT transmission equipment.
- A Lambda takes between 4 and 6 weeks to establish, due mainly to the lead time for the GÉANT optical equipment. The lead time for 100 Gbps may be longer.
- An additional charge is raised to cover the cost of each Lambda requested.

- A Lambda can be used as part of an E2E link, and in conjunction with a partner organisation, to connect to a non-GÉANT organisation/destination.
- During Year 4, the new Infinera-equipped transmission network has been installed, which can support Generalised Multi-Protocol Label Switching (GMPLS) which in turn can add flexible re-routing capabilities in the future. If the requirement is to protect against failure of the NREN-facing port, a full back-up Lambda can be provided on an alternative port.

1.3.2.3 *Availability*

The provision of the GÉANT Lambda service is dependent on the use of dark fibre for the underlying infrastructure. For reasons relating to the availability and/or economic viability of dark fibre, it is not possible to offer point-to-point services to all GÉANT-connected NRENs.

2 Use of Advanced Services in Year 4

2.1 Overview

5 new point-to-point links were delivered in Year 4 of GN3 (1 April 2012 to 28 February 2013[2]): 4 GÉANT Plus and 1 GÉANT Lambda. This compares with 14 delivered during the previous year (Year 3). All the links were in addition to those ordered and delivered in previous years. 9 links were cancelled (7 GÉANT Plus, 2 GÉANT Lambda), bringing the total number of links in use at Year 4 end to 65 (44 GÉANT Plus, 21 GÉANT Lambda).

This section summarises the new links delivered in Year 4, and cancellations, and provides statistics for the total number of links in use as at Year 4 end. Further information about the projects is given in Appendix A "Projects" on page 24.

2.2 New Links

Table 2.1 shows all new point-to-point links delivered in GN3 Year 4, sorted by Project.

SRF No.[1]	Bandwidth assigned (approx.)[2]	A-End Domain	B-End Domain	Project	Production Date[3]	GÉANT Plus / Lambda
12-010	n/a	JANET	SURFnet	eLVBI	07-May-2012	Plus
12-012	n/a	CERN	NIIFI / Hungarnet	WIGNER	18-Jul-2012	Plus
12-013	n/a	CERN	JSCC	LHC	12-Jul-2012	Plus
12-014	100 Gbps	CERN	NIIFI / Hungarnet	LHC	17-Jan-2013	Lambda
13-001	n/a	ACOnet	ARNES	LOLA	19-Feb-2013	Plus

Table 2.1: New point-to-point links delivered in Year 4 – 1 April 2012 to 28 February 2013

[2] The latest date for which figures are available at the time of writing.

Key:

1. SRF = Service Request Form. Each order is placed using such a form and assigned a unique SRF number, which is then used to designate the point-to-point link.
2. No bandwidth limitation is now applied on GÉANT Plus circuits by default.
3. Production Date = Date that DANTE Operations handed the link over to the NREN for the project to use.

The new Lambda link for LHC was the first 100 Gbps service that DANTE has ever provided, and connects CERN in Geneva with the new hosting centre in Budapest.

2.3 Cancelled Links

2.3.1 GÉANT Plus

7 GÉANT Plus services were cancelled during Year 4, 4 of which were for connecting to the initial Alcatel AutoBAHN testbed, as NRENs can now connect to the production Juniper equipment to use AutoBAHN. The remaining 3 cancelled GÉANT Plus services were for FEDERICA, AtlantIC and JSTOR.

2.3.2 GÉANT Lambda

2 GÉANT Lambda services were cancelled during Year 4, one for I2CAT and another for an NREN connection to StarLight.

2.4 Total Links in Use

2.4.1 GÉANT Plus

At the end of Year 4, 44 GÉANT Plus links are in use. The total reflects all currently installed links, both those installed in previous years and during Year 4. Figure 2.1 shows these links broken down by project.

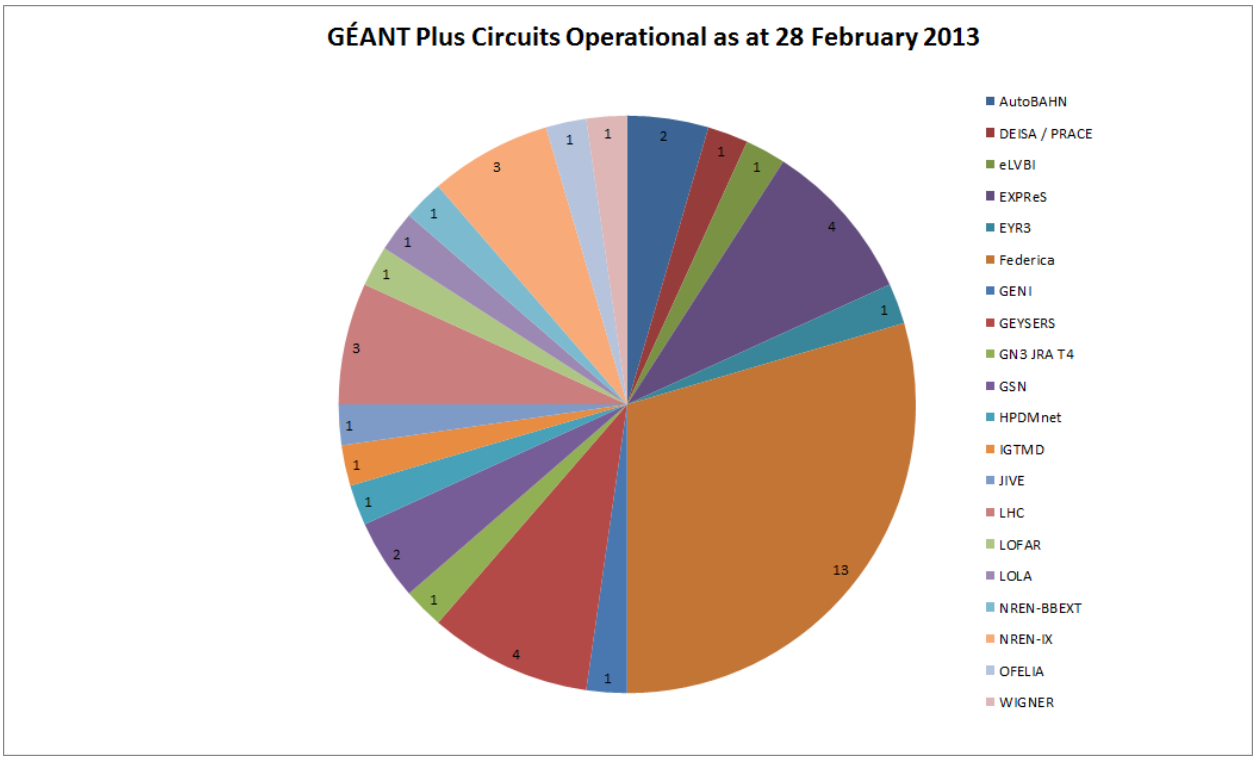

Figure 2.1: Number of GÉANT Plus links as at the end of Year 4

Notes:

1. The project name “NREN-IX” denotes an NREN–Internet Exchange (IX) link, which connects a specific NREN to a specific commercial IX. These links pre-date GÉANT’s own IX connections.
2. The project name “NREN-BBEXT” refers to the situation where an NREN uses the GÉANT Plus or Lambda service to connect two areas of their backbone.

2.4.2 GÉANT Lambda

As at the end of Year 4, 21 GÉANT Lambda links are in use. The total reflects all currently installed links, both those installed in previous years and during Year 2. Figure 2.2 shows these links broken down by project.

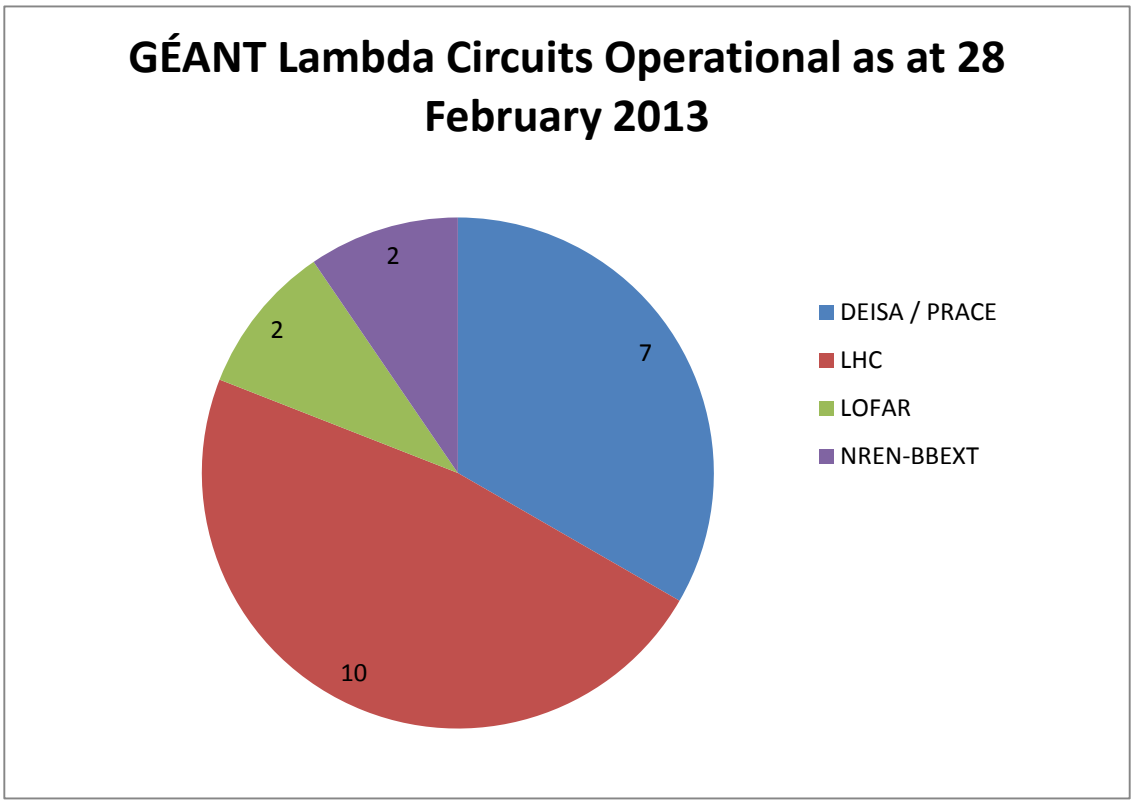

Figure 2.2: Number of GÉANT Lambda links as at the end of Year 4

Notes:

1. The project name "NREN-BBEXT" refers to the situation where an NREN uses the GÉANT Plus or Lambda service to connect two areas of their backbone.

2.4.3 Combined Totals

Figure 2.3 shows the projects' use of both link types, expressed as a percentage of the combined total. The largest users of the GÉANT advanced services are FEDERICA and LHC (each 13 links, 20%), followed by DEISA / PRACE with 8 circuits. All the other projects use 4 or fewer circuits. The ongoing effort to support AutoBAHN and the Bandwidth on Demand service is part of the GÉANT project, although the automatically created user services are not included in these statistics. Together with the end-user projects on whose behalf the NRENs have requested circuits, AutoBAHN is a direct beneficiary of GÉANT advanced services. The total of 65 also excludes any wavelengths that are used to support GÉANT Plus capacity or IP trunks between GÉANT backbone routers.

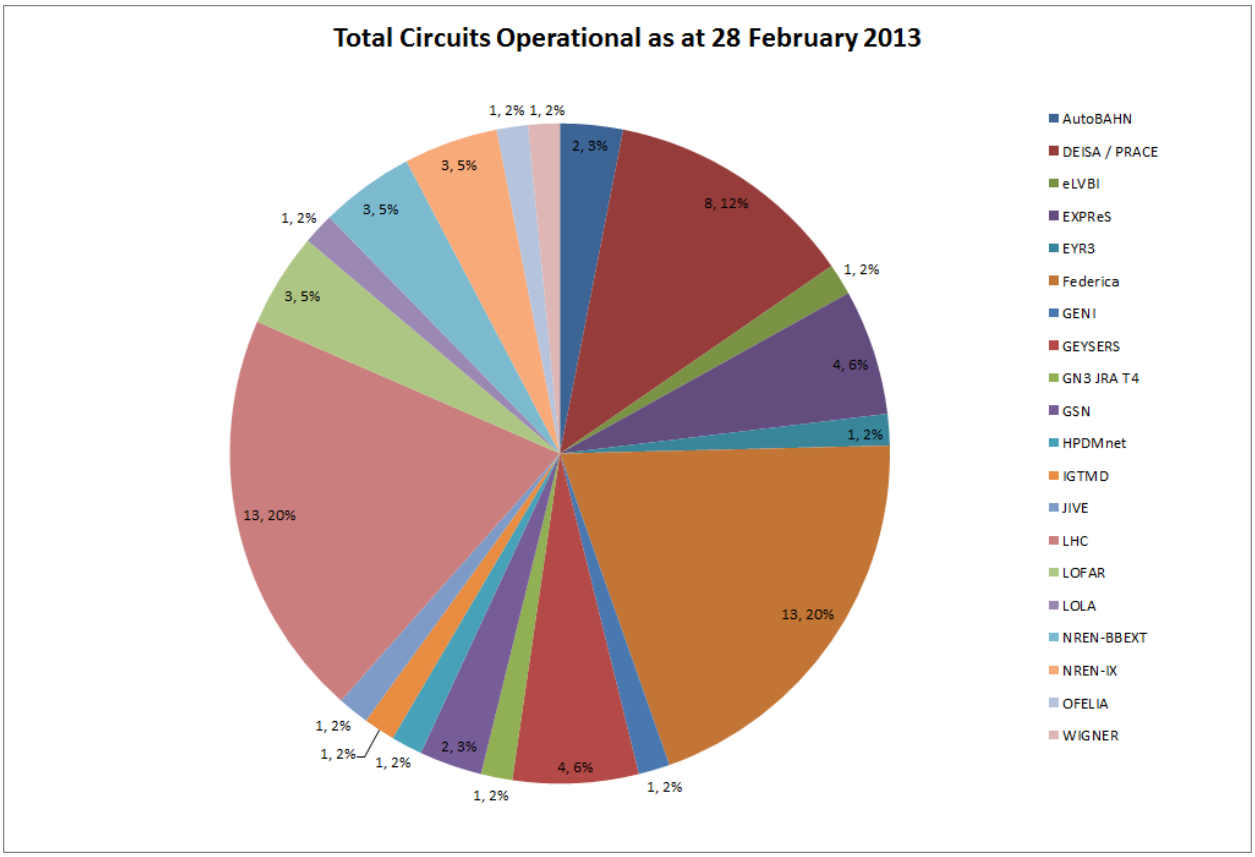

Figure 2.3: Projects' use of both link types combined as at the end of Year 4

Notes:

1. The project name "NREN-IX" denotes an NREN–Internet Exchange (IX) link.
2. The project name "NREN-BBEXT" refers to the situation where an NREN uses the GÉANT Plus or Lambda service to connect two areas of their own backbone.

2.5 Trends

Table 2.2 below shows the trend for new, cancelled and total numbers of links since the start of the GN3 project. The totals at the start of the project were:

- GÉANT Plus: 27.
- GÉANT Lambda: 23.
- Combined total: 50.

Links	Year 1			Year 2			Year 3			Year 4		
	GÉANT Plus	GÉANT Lambda	Total	GÉANT Plus	GÉANT Lambda	Total	GÉANT Plus	GÉANT Lambda	Total	GÉANT Plus	GÉANT Lambda	Total
New	8	4	12	6	3	9	10	4	14	4	1	5
Cancelled	3	2	5	7	4	11	11	2	13	7	2	9
Total at year end	41	23	64	47	21	68	45	23	68	44	21	65

Table 2.2: Trends since the start of GN3

GÉANT continues to serve many circuit users, with the total number of links at the end of Year 4 almost unchanged from the total at the start of the project (65 versus 64). The relatively low growth over the lifetime of the project reflects the maturity and stable requirements of the projects supported (following strong demand in their early years), the lack of new projects as FP7 comes to an end, and projects looking at alternative methods of connecting NRENs, such as dynamic circuits.

2.6 Layer 3 VPN Service

DANTE continues to provision and support several connections from NRENs to the Layer 3 VPN service for the Large Hadron Collider Open Network Environment (LHCONE). LHCONE is designed to connect the LHC Tier 1 and Tier 2 sites using Border Gateway Protocol / Multi-Protocol Label Switching technologies.

3 The E2ECU Function

E2E circuits are multi-domain, that is, they are composed of multiple sections, each administered by a different domain, usually but not always including the GÉANT backbone. At least two domains will therefore participate in circuit provisioning and management.

The End-to-End Coordination Unit (E2ECU) is responsible for the overall monitoring of E2E circuits and for coordinating the information flow and communications between the actors in the different domains involved in each E2E circuit. The constituent links in the circuit are also monitored by the appropriate national or international Network Operations Centre (NOC), such as the NREN NOC or the GÉANT NOC. The E2ECU is operated by DANTE via its outsourced Service Desk and in-house Network Control Centre NOC functions.

This section describes the responsibilities of the E2ECU, the role of the central End-to-End Monitoring System (E2EMon), the Trouble Tickets (TT) procedure, and plans for future service development.

For more information about the E2ECU's processes, procedures and tools, including the role played by the GÉANT network-monitoring service PerfSONAR and the End-to-End Monitoring System (E2EMon), see [DN3.0.5].

3.1 E2ECU Responsibilities

For the E2E circuits under its supervision, the E2ECU ensures that:

- Trouble Tickets (TTs) are opened when a fault, such as a fibre cut, occurs that affects the E2E circuit. (The E2ECU uses plug-ins for the proprietary monitoring system so that it receives alerts from E2EMon whenever an E2E circuit has an outage on any of its constituent parts.)
- TTs related to any fault affecting an E2E circuit are updated and forwarded to all the domains involved.
- TTs are raised for any scheduled outages (due to planned maintenance, for example) about which the E2ECU has been notified by the constituent networks (such as GÉANT and NRENs).
- TTs related to any scheduled outage affecting an E2E circuit are updated and forwarded to all the domains involved.

Connectivity incidents detected through the multi-domain monitoring systems are reported to all the parties involved on a 24x7 basis via emailed Trouble Tickets. Updates on incident resolution are given 07:00 to 22:00

CE(s)T Monday to Friday. During this time the E2ECU will contact the NOC of the domain in which the fault has occurred to obtain further details, and will forward this information to the other parties involved.

The E2ECU creates monthly reports, made available to the NRENs, which include availability statistics for the various point-to-point links and a list of point-to-point links recently added to E2EMon.

The E2ECU is currently resourced at the level of 0.5 full-time equivalent.

3.2 Role of E2EMon

The central End-to-End Monitoring System (E2EMon) represents each physical E2E link as being formed of "domain links" and "inter-domain links". In E2EMon, a domain link is a link that is contained within a single network, such as across the GÉANT network. An inter-domain link (IDL) is a link between two neighbouring domains, such as GÉANT and RENATER; it is divided into two parts, with half of the link in each domain. In reality, an IDL may be a patch cable between two pieces of transmission equipment or a telco-provided circuit between sites.

Using Simple Network Management Protocol (SNMP), E2EMon polls the individual domain Measurement Points (MPs) and Measurement Archives (MAs) every five minutes to gather information about the constituent domain and inter-domain links. Since each domain and link is tagged as belonging to a particular E2E circuit and names its neighbour domains, E2EMon can concatenate the status of the constituent links to represent the E2E circuit; this is shown on a graphical display that can be viewed with a web browser. The E2ECU receives alerts from E2EMon whenever an E2E circuit has an outage on any of its constituent parts.

The E2EMon website shows three types of errors:

- Apparent outages on the end-to-end links (learnt from the MP or MA, whichever the organisation provides).
- Errors in the configuration of these MPs/MAs that mean the future outage information is not reliable.
- Connectivity problems to the MPs/MAs.

Access to E2EMon is managed by DANTE. In addition to the E2ECU, any party who maintains a network that is represented on E2EMon is permitted access. This includes the GÉANT NOC, GÉANT NRENs, CERN, Internet2, ESnet and Fermilab.

3.3 Trouble Tickets Procedure

The E2ECU may be notified of an outage either by E2EMon or by someone in the domain. On being notified, the E2ECU raises a Trouble Ticket (TT) containing information such as the names of the domain link or inter-domain links affected, the name(s) of the domain(s), the name of the project affected, and the time of the outage.

The E2ECU then contacts the organisations of the relevant domains to request information regarding the outage and to assist them in interpreting the errors; in the case of an inter-domain link, the E2ECU will contact both domains involved.

The E2ECU distributes any updates regarding the outage to all partners in the project affected.

4 E2ECU Activity in Year 4

4.1 Overview

During Year 4, E2ECU monitored a total of 35 circuits for 3 projects: LHCOPN (24), DEISA (10) and IGTMD (1). These links require global monitoring because multiple networks, some outside Europe, contribute sections of the links from end to end. A total of 349 Trouble Tickets (TTs) were tracked and closed.

4.2 Trouble Ticket Statistics

Figure 4.4 shows the number of Trouble Tickets (TTs) closed each month for the E2ECU projects over Year 4, as of 21 February 2013.

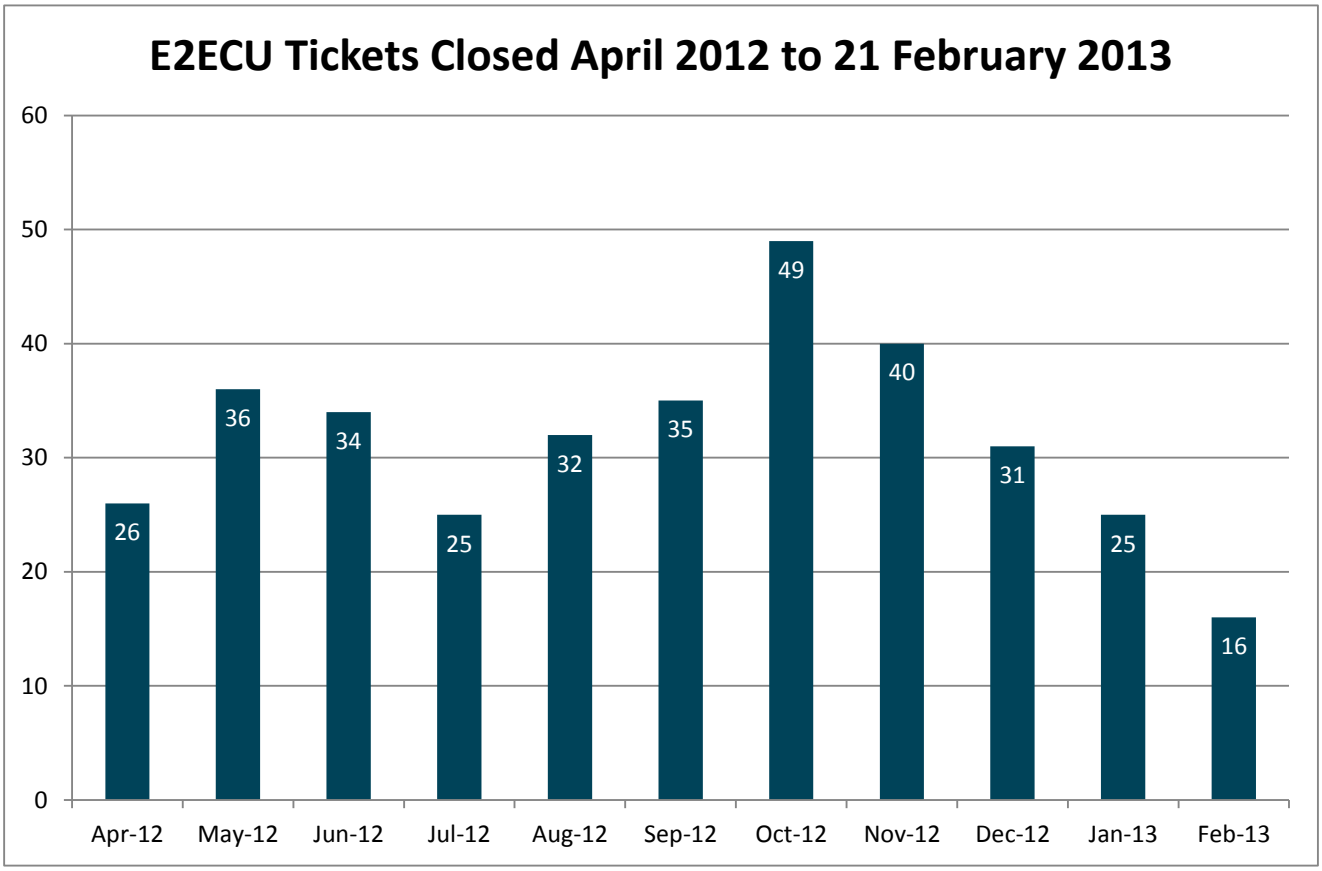

Figure 4.4: Number of E2ECU tickets closed each month 1 April 2012 to 21 February 2013

Whilst some of these tickets reflect valid connectivity faults successfully captured using the E2EMon tool, there are still several occasions where the E2EMon system and associated NREN-created and maintained scripts are generating alarms that the NOCs are unable to map to real outages, hence many tickets are closed with "no reason for the outage report".

In the previous year, Year 3, the E2ECU monitored a total of 32 circuits for the same three projects, and closed 534 TTs (185 more). The difference reflects the fact that most MP incidents (i.e. problems with the connectivity or configuration of the MPs, meaning that the monitoring function itself is broken) are now handled directly by the GN3 SA2 Task 2 (Multi-Domain Network Services, Multi-Domain Service Coordination and Operation) team of experts rather than the E2ECU, since the SA2 team has expert software knowledge and can assist the NRENs in resolving such problems as quickly as possible. The E2ECU continues to handle link outage incidents.

5 Multi-Domain Service Desk

Following a successful pilot phase, the Multi-Domain Service Desk (MDSD) was successfully launched into production and live service in June 2012. The MDSD provides support and monitoring for various multi-domain services across the GÉANT community and is operated by the DANTE NOC.

The launch of a MDSD has been successful in that defined query and incident management processes, including escalation, have been followed and proven to resolve issues brought to it by the GÉANT NRENs.

The MDSD provides support for the following services and tools:

- Bandwidth on Demand.
- perfSONAR.
- AutoBAHN.
- I-SHARe.
- cNIS.

During the course of the trial and the early months of the live service, MDSD staff have gained experience and better understood the above services and tools though familiarisation exercises and directed training sessions.

For more complex queries, the MDSD escalates the issues to various Subject Matter Experts within SA2. Full details of the MDSD are available on the Partner Portal [PP_MDSD].

6 Plans for Service Development

This section gives an overview of the plans for development in each of the areas covered by the preceding sections of the document, namely, advanced services, E2ECU and E2EMon, and the MDSD.

6.1 Advanced Services

The website for NREN partner users of GÉANT's services, and of the advanced services in particular, was launched in Year 2 (see Figure 6.5 below and [PP]). Known as the Partner Portal, the site was designed to enable NRENs to manage their GÉANT account and services, including obtaining more information about and requesting new services. The portal continues to be well used, providing each NREN with up-to-date information on their GÉANT service usage, hosting GÉANT backbone service definitions, and facilitating service requests. It also provides NRENs with news and information about developments within the GÉANT project via a News page [PP_News] that is linked to from a quarterly newsletter issued by the Partner Relations team. The Partner Portal is therefore a key service/account management and communications tool for the NREN users of GÉANT's advanced services, hence its inclusion here.

Development of the site is ongoing, with plans to include content on all GÉANT services such as Bandwidth on Demand and perfSONAR by the end of Year 4, and to introduce a new GÉANT NREN Tools Gateway page during GN3plus Year 1, to provide an easy overview of and access to all GÉANT account management tools. Details of the Tools Gateway page are still being finalised, but its objectives are:

- For NRENs:
  - Usability: improve the usability of the Partner Portal, making it easier to locate information.
  - Integration: provide a one-stop shop to NRENs by integrating (at least visually/using Single Sign-On) the existing Partner Portal with the Tools Portal.
  - Completeness: ensure the Portal is a comprehensive source of information, including services, the network and (secure) access to invoices.
- For internal project use:
  - Reporting and automation tools: enable better use of the data stored in the Portal.

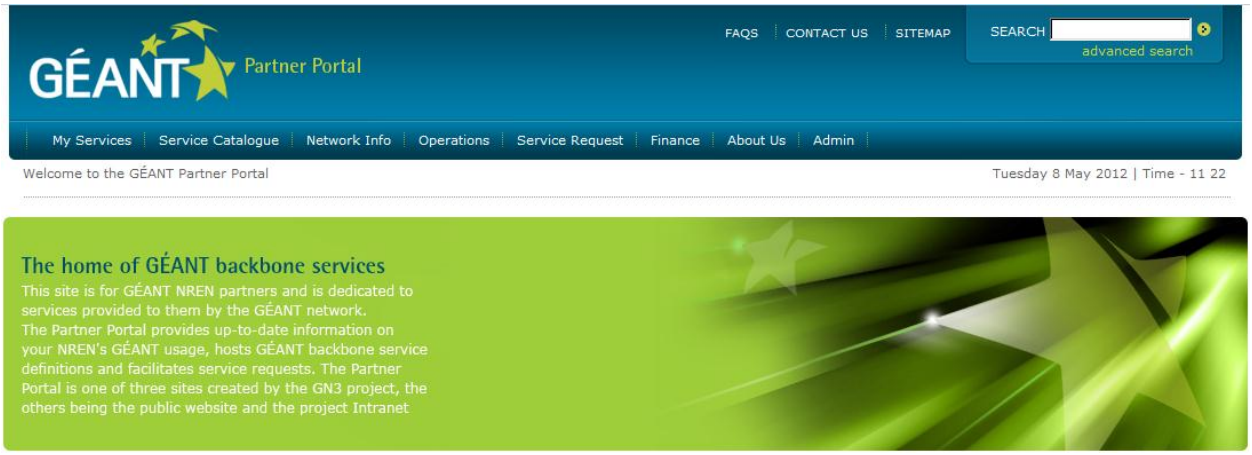

Figure 6.5: Partner Portal home page

6.2 E2ECU and E2EMon

A major challenge for NRENs and the DANTE staff maintaining the GÉANT backbone is the creation, configuration and maintenance of the software elements associated with the Measurement Point (MP) and Measurement Archive (MA) software. These are vendor specific and usually need to be rewritten or updated if the vendor changes or if the version of vendor software changes. Such ongoing work is resource intensive and if such resources are not allocated in a timely fashion, the information provided to E2EMon by the various organisations becomes increasingly unreliable. This greatly impacts the reliability and trustworthiness of the E2EMon system as a whole, since E2E links are no longer fully or accurately monitored. DANTE and the GN3 SA2 Task 2 team have therefore drawn up plans to simplify support for multi-domain services in preparation for GN3plus. At the end of February 2013, support for the E2EMon software will cease and E2ECU responsibilities will transfer to the GÉANT MDSD and GÉANT NOC, who will implement processes that are better matched to existing NREN workflows.

Support for NRENs working with end-to-end links that were previously supported by the E2ECU and E2EMon will continue to be provided as follows:

- Notification of planned work that will affect end-to-end links will be provided by the MDSD Planned Maintenance Calendar [MDSDCal].
- The GÉANT NOC will be the central coordination and communication point for receiving and disseminating reports of outages in NREN networks that affect end-to-end links. The GÉANT NOC will advertise key messages, learnt from NREN NOCs and GÉANT NOC software, to relevant other NRENs involved, who can then pass messages to their client sites as appropriate.

Access Port Managers (APMs) have been advised accordingly.

A new monitoring solution, named CMon (Circuit Monitoring) is planned to be developed during the GN3plus project as part of SA4 Network Support Services. CMon will support static circuits (those that have been discussed in this document) and dynamic circuits (those created using tools such as AutoBAHN), and will

require less ongoing software development within the network organisations. It is expected that CMon will be more fully integrated with the perfSONAR software suite than E2EMon, allowing a robust monitoring system. A prototype will be demonstrated in March 2013, after which the tool will be more fully developed during the GN3plus project, with a goal of March 2014 for the production release. Further information is available at [CMon].

6.3 MDSD

In addition to its current remit, the MDSD will also assume responsibility for the coordination of multi-domain circuit faults during GN3plus.

7 Conclusions

The GÉANT network was the first international production hybrid network, combining the operation of a shared IP infrastructure with the ability to provide additional dedicated point-to-point links. During 2012, this hybridisation has been taken to a new level, with the introduction of new, cutting-edge equipment. The three levels of connectivity service reflect the immense flexibility that the network has been designed to offer, with the advanced services, GÉANT Plus and GÉANT Lambda, meeting the requirements for privacy, security, availability, capacity, robustness and speed of the most demanding user projects.

Utilisation of GÉANT point-to-point services remains strong and several new circuit requests has been received with 5 new links delivered in Year 4. This compares with 14 new links in Year 3. Whilst GÉANT continues to serve many circuit users, it is expected that, in the future, some projects will be looking at alternative methods of connecting NRENs, such as dynamic circuits. These would be greatly supported by the GN3 Bandwidth on Demand project and the GÉANT AutoBAHN software, which has seen a significant increase in uptake during Year 4. The upgrade of the GÉANT backbone hardware is also expected to facilitate a reduction in lead time for fixed circuit services.

The expected increase in use of dynamic circuit services necessitates a review and improvement of the associated pan-community circuit monitoring and support services to enable support of these short-term, automatically created circuits. This also gives us an opportunity to improve the monitoring tools for the static services, of which GÉANT Plus and GÉANT Lambda form part of the portfolio. The Multi-Domain Service Desk will play an increasingly important role in providing these multi-domain circuit monitoring and support services.

Building on the experience gained in recent years, a process of continuous improvement is underway to develop and enhance the point-to-point procedures and services still further.

Appendix A Projects

A.1 Summary

Table A.3 lists (in alphabetic order) the projects using GÉANT advanced services and/or supported by the E2ECU, and gives the URL of their respective websites, from which further information can be obtained.

Project	URL
AtlantIC	http://www.atlanticcalliance.org/
AutoBAHN	http://www.geant.net/service/autobahn/pages/home.aspx
DEISA/PRACE	http://www.deisa.eu and http://www.prace-ri.eu/
eLVBI	http://www.evlbi.org/evlbi/
EXPReS	http://www.expres-eu.org/
EYR3	http://www.surfnet.nl/nl/thema/eyr/Pages/Default.aspx
FEDERICA	http://www.fp7-federica.eu
GENI Testbed	http://www.geni.net/
GEYSERS	http://www.geysers.eu/
GreenStar Network	http://www.greenstarnetwork.com/
HPDMnet	http://www.hpdmnet.net/
i2CAT	http://www.i2cat.net/en
IGTMD	http://www.ens-lyon.fr/LIP/RESO/Projects/IGTMD/ProjetIGTMD.html
JIVE	http://www.jive.nl/about-jive
LHCOPN	http://public.web.cern.ch/public/en/LHC/LHC-en.html
LOFAR	http://www.lofar.org/
LOLA	http://www.conservatorio.trieste.it/artistica/ricerca/progetto-lola-low-

Project	URL
	latency/
OFELIA	http://www.fp7-ofelia.eu/
WIGNER	http://wigner.mta.hu/wignerdc/

Table A.3: Projects using GÉANT advanced services – names and URLs

A.2 Key Projects

The projects with more than one point-to-point link are briefly described below.

For further information about GÉANT's most demanding users, see [DN3.0.3,3].

A.2.1 AutoBAHN

The Automated Bandwidth Allocation across Heterogeneous Networks (AutoBAHN) system is an automated bandwidth provisioning system for reservation and allocation of network paths, currently at prototype stage. AutoBAHN can provide a Bandwidth on Demand service by configuring on-demand circuits across various networks. The objective of the AutoBAHN Task of the GN3 project is to enhance the AutoBAHN prototype with functionality, extending it to other layers and technologies for dynamic circuit provisioning and improving existing modules (e.g. path-finding computations) or revising its functions where necessary to make them easier to manage and maintain. AutoBAHN will mature so as to be integrated in the multi-domain services portfolio of GN3.

While AutoBAHN is a GÉANT service, the ongoing GN3 effort to support it using advanced services is treated as a project in the same way as the end-user projects on whose behalf the NRENs have requested circuits.

For more information, see http://www.geant.net/service/autobahn/pages/home.aspx.

A.2.2 DEISA / PRACE

The Distributed European Infrastructure for Supercomputing Applications (DEISA) is a consortium of leading national supercomputing centres. It aims to foster pan-European world-leading computational science research and to build and operate a distributed terascale supercomputing facility. DEISA provides access to European tier-1 systems and offers a small part of their computing resources to European projects.

The mission of the Partnership for Advanced Computing in Europe (PRACE) is to enable high-impact scientific discovery and engineering research and development across all disciplines to enhance European competitiveness for the benefit of society. PRACE seeks to realise this mission by offering world-class

computing and data management resources and services through a peer review process. PRACE also seeks to strengthen the European users of high performance computing in industry through various initiatives. PRACE has a strong interest in improving the energy efficiency of computing systems and reducing their environmental impact.

PRACE and DEISA collaborate closely, and are working together on middleware developments for ecosystem integration.

For more information, see http://www.deisa.eu and http://www.prace-ri.eu/.

A.2.3 EXPReS

Express Production Real-time e-VLBI Service (EXPReS) is a three-year project to create a distributed astronomical instrument of continental and intercontinental dimensions using real-time, electronic Very Long Baseline Interferometry (e-VLBI). e-VLBI uses fibre-optic networks, including GÉANT links, to connect 16 radio telescopes on 6 continents to the central data processor at the Joint Institute for Very Long Baseline Interferometry in Europe (JIVE), in the Netherlands, a purpose-built supercomputer which correlates data from the telescopes in real-time. Transferring data electronically and correlating it in real-time eliminates weeks of waiting from the current VLBI method of storing data on disks and shipping them to the correlator for processing. This allows researchers to take advantage of Targets of Opportunity for conducting follow-on observations of transient events such as supernova explosions and gamma-ray bursts. e-VLBI also allows high precision tracking of space probes.

For more information, see http://www.expres-eu.org/.

A.2.4 FEDERICA

The Federated E-infrastructure Dedicated to European Researchers (FEDERICA) was a project designed to implement an experimental network infrastructure for trialling new networking technologies. The infrastructure is intended to be neutral as to the type of protocols, services and applications that may be trialled, whilst allowing disruptive experiments to be undertaken. The aim was to develop mechanisms that will allow such experiments to be run over existing production networks without adverse effect. Although the project ended in October 2010, its infrastructure remains in place and operational and is used by projects such as Networking innovations Over Virtualised Infrastructures (NOVI), IPsphere and GÉANT. GÉANT currently uses it to interconnect the testbed resources of its virtualisation service GENUS.

For more information, see http://www.fp7-federica.eu.

A.2.5 GEYSERS

Generalised Architecture for Dynamic Infrastructure Services (GEYSERS) is a project funded under the European Union's Seventh Framework Programme. A consortium of NRENs, universities, research institutions,

subject-matter experts and manufacturers, its goal is to qualify optical infrastructure providers and network operators with a new architecture, to enhance their traditional business operations.

GEYSERS's vision is to deliver:

- A novel architecture capable of:
  - Seamless and coordinated provisioning of optical & IT resources.
  - End-to-end service delivery to overcome limitations of network domain segmentation.
- A novel business framework for infrastructure providers and network operators.
- A novel mechanism to partition infrastructure resources and compose logical infrastructures.
- A cost- and energy-efficient proof-of-concept implementation.

For more information, see http://www.geysers.eu/.

A.2.6 GreenStar

The GreenStar Network (GSN) is a CANARIE-funded project led by École de Technologie Supérieure (Synchromedia). The goal of the GSN project is to create technology and standards for reducing the carbon footprint of Information and Communication Technology (ICT). ICT is responsible for 2% of global CO_2 emissions, due to high consumption of electricity produced from coal.

HEAnet is a key European partner in GSN, and is installing wind- and solar-powered hub nodes for the project's extended network. Three GÉANT Plus circuits are used to transport data relating to the project across the Atlantic.

For more information, see http://www.greenstarnetwork.com/.

A.2.7 IGTMD

IGTMD (Interopérabilité des Grilles de Calcul et Transferts Massifs de Données) is a Franco-American project whose goal is the interoperability of two grids: Enabling Grids for E-scienceE (EGEE) and Open Science Grid (OSG14). The project is particularly concerned with addressing the challenges of transferring vast quantities of data over very long distances. The two main centres are the National Institute of Nuclear and Particle Physics (IN2P3) in Lyon and the Fermi National Accelerator Laboratory (FNAL15) in Chicago.

For more information, see http://www.ens-lyon.fr/LIP/RESO/Projects/IGTMD/ProjetIGTMD.html.

A.2.8 LHCOPN

The Large Hadron Collider (LHC) is the most ambitious project undertaken by CERN to date.

CERN is the world's largest organisation for research into particle physics. Based in Switzerland and funded by 20 European member states, CERN is a world-wide enterprise involving scientists of many nationalities. It is a prime example of international collaboration, as many experiments conducted at CERN are on such a scale that no single state could afford to fund them.

The LHC project is now live and has already demonstrated some exciting results. The project accelerates particles to previously impossible energies, producing short-lived and never-before-seen results. It is predicted to produce data at the rate of 15 Petabytes (15 million Gigabytes) per annum. It has been decided to process all this data not in one institution, but using a grid – the Worldwide LHC Computer Grid (WLCG) – so the results will be distributed by GÉANT and connected NRENs to analysis sites around the globe.

For more information, see http://public.web.cern.ch/public/en/LHC/LHC-en.html.

A.2.9 LOFAR

LOw Frequency ARray (LOFAR) is a multi-purpose sensor array. Its main application is astronomy at low frequencies (10-250 MHz) but it also has geophysical and agricultural applications. Its heart is currently being assembled in the Northeast of the Netherlands and spreads over the whole country and over whole Europe.

LOFAR is the first telescope of its kind, using an array of simple omni-directional antennas instead of mechanical signal processing with a dish antenna. The electronic signals from the antennas are digitised, transported to a central digital processor, and combined in software to emulate a conventional antenna. The full LOFAR design involves about 7,000 antennas. To make radio pictures of the sky with adequate sharpness, these antennas are arranged in clusters that are spread out over an area of 100 km in diameter within the Netherlands and over 1500 km throughout Europe. Data transport requirements are in the range of many Tera-bits/sec and the processing power needed is tens of Tera-FLOPS.

For more information, see http://www.lofar.org/.

Appendix B GÉANT Topology

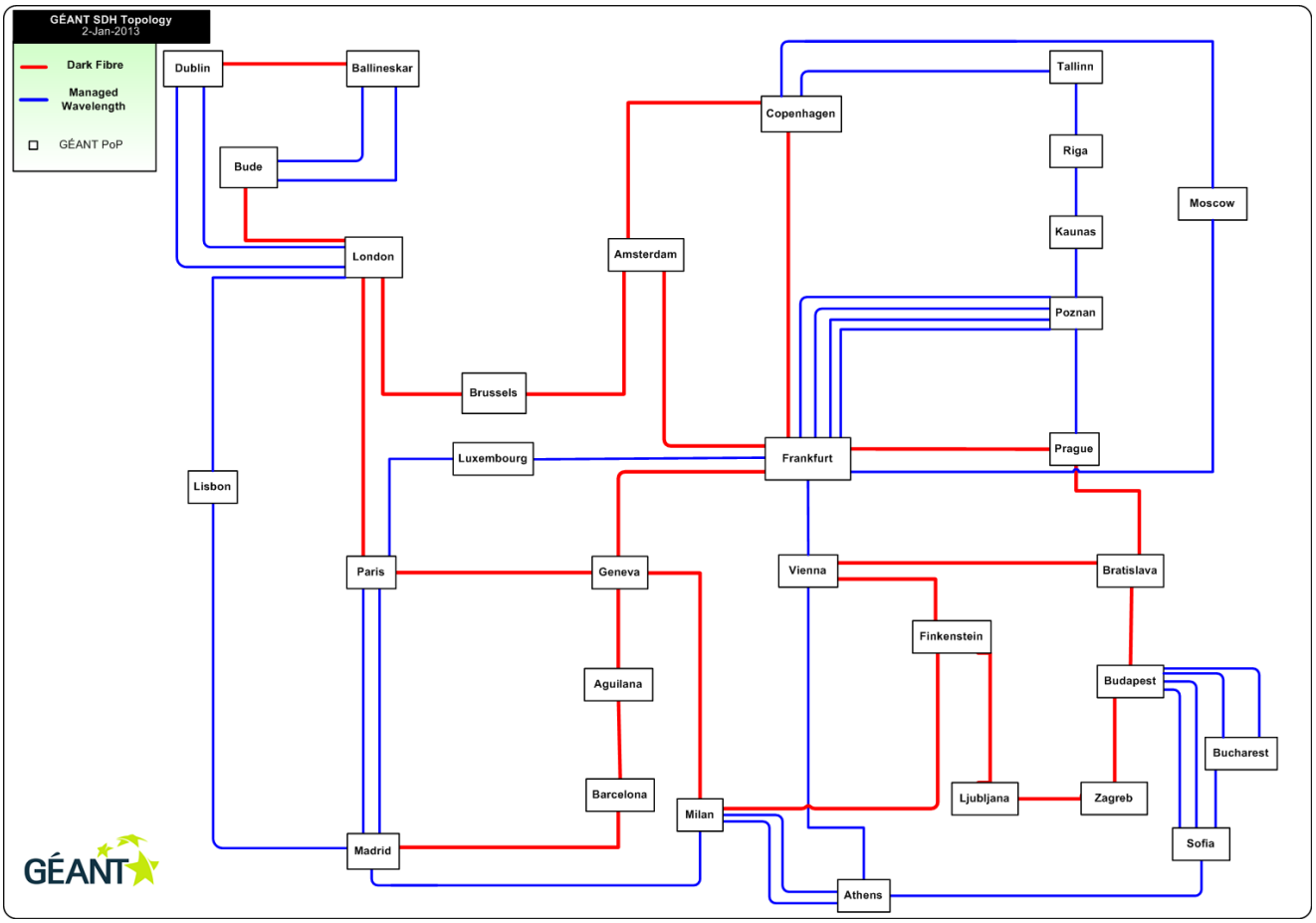

Figure B. 1: GÉANT topology as at 2 January 2013

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[DN3.0.5]	GN2-07-131v08 “Deliverable DN3.0.5: Processes and Provision of Point-to-Point Services in GÉANT2” http://www.geant2.net/upload/pdf/GN2-07-131v8-DN3-0-5_Processes_and_Provision_of_Point-to-Point_Services.pdf
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[PP]	GÉANT Partner Portal https://partner.geant.net/Pages/Home.aspx [username and password required]
[PP_MDSD]	GÉANT Partner Portal MDSD page https://partner.geant.net/Operations/MDSD/Pages/MultiDomainServiceDesk.aspx [username and password required]
[PP_News]	GÉANT Partner Portal News page https://partner.geant.net/news [username and password required]
[PP_Services]	GÉANT Partner Portal Services Catalogue page https://partner.geant.net/Service_Catalogue/pages/home.aspx [username and password required]

Glossary

APM	Access Port Manager
AutoBAHN	Automated Bandwidth Allocation across Heterogeneous Networks
CERN	European Organisation for Nuclear Research
CE(s)T	Central European (summer) Time
CMon	Circuit Monitoring
cNIS	Common Network Information Service
DEISA	Distributed European Infrastructure for Supercomputing Applications
DWDM	Dense Wavelength-Division Multiplexing
E2E	End-to-End
E2ECU	End-to-End Coordination Unit
E2EMon	End-to-End Monitoring System
EGEE	Enabling Grids for E-scienceE
e-VLBI	electronic Very Long Baseline Interferometry
EXPReS	Express Production Real-time e-VLBI Service
FEDERICA	Federated E-infrastructure Dedicated to European Researchers
FNAL15	Fermi National Accelerator Laboratory
GE	Gigabit Ethernet
GEYSERS	Generalised Architecture for Dynamic Infrastructure Services
GMPLS	Generalised Multi-Protocol Label Switching
GSN	GreenStar Network
ICT	Information and Communication Technology
IDL	Inter-Domain Link
IGTMD	Interopérabilité des Grilles de Calcul et Transferts Massifs de Données
IN2P3	National Institute of Nuclear and Particle Physics
IP	Internet Protocol
I-SHARe	Information Sharing Across Heterogeneous Administrative Regions
IX	Internet Exchange
JIVE	Joint Institute for Very Long Baseline Interferometry in Europe
L2	Layer 2
LHC	Large Hadron Collider
LHCONE	LHC Open Network Environment
LHCOPN	LHC Optical Private Network
LOFAR	LOw Frequency Array
LOLA	LOw LAtency

MA	Measurement Archive
MDSD	Multi-Domain Service Desk
MP	Measurement Point
MPLS	Multi-Protocol Label Switching
NOC	Network Operations Centre
NOVI	Networking innovations Over Virtualised Infrastructures
NREN	National Research and Education Network
OFELIA	OpenFlow in Europe, Linking Infrastructure and Applications
OSG	Open Science Grid
PerfSONAR	Performance-focused Service Oriented Network monitoring ARchitecture
PoP	Point of Presence
PRACE	Partnership for Advanced Computing in Europe
SA2	GN3 Service Activity 2 Multi-Domain Network Services
SA2 T2	SA2 Task 2 Multi-Domain Service Coordination and Operation
SDH	Synchronous Digital Hierarchy
SNMP	Simple Network Management Protocol
SRF	Service Request Form
TT	Trouble Ticket
VPN	Virtual Private Network
WIGNER	Wigner Research Centre for Physics, Budapest, Hungary – CERN data centre
WLCG	Worldwide LHC Computer Grid