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Deliverable D5.29 (DS1.3.4,2) GÉANT Service Uptake – Year 2

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Abstract
This deliverable reports on the take-up and usage of GÉANT's core advanced services, GÉANT Plus and GÉANT Lambda, during Year 2 of the GN3Plus Project. It describes each service and provides figures for new point-to-point circuits delivered. It also provides an update on the overall status of advanced services, network developments, and the new types of services recently implemented.

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Executive Summary

This deliverable reports on the take-up and usage of GÉANT's core advanced services, GÉANT Plus and GÉANT Lambda, during Year 2 of the GN3Plus Project. It gives a description of each service and provides figures for new point-to-point circuits delivered. It also provides an update on the overall status of advanced services, network developments and the new types of services recently implemented.

In addition to the standard GÉANT IP service which provides access to the shared European Internet Protocol (IP) research and academic network, GÉANT offers two distinct types of point-to-point services to NRENs (GÉANT Plus and GÉANT Lambda) which are free from the constraints inherent in the public Internet.

A total of 26 new point-to-point circuits, (20 GÉANT Plus and 6 GÉANT Lambda) were delivered on the GÉANT infrastructure during Year 2, bringing the total number of circuits in use at the end of Year 2 to 112 (80 GÉANT Plus, and 32 GÉANT Lambda). The Large Hadron Collider (LHC) project and GÉANT Testbed Service (GTS) have the most circuits, with 12 each.

The reach of the GÉANT Plus service is continually expanding to provide connectivity for more organisations in a growing number of countries.

The LHC Open Network Environment (LHCONE) remains the biggest L3VPN user, with another project participant connected in Y2 bringing that number to 15.

Also, the GÉANT Open service, which enables research organisations to connect to each other via a protocol-neutral switch, is now fully in production and already has multiple 100G connections in London. Multi-Domain services continue to be supported by the GÉANT Operations Centre.

1 Introduction

The GÉANT network offers the European research and education community a unique range of communication opportunities for international collaboration. GÉANT is a hybrid network, combining the operation of an optical transport and Internet Protocol (IP) infrastructure with the ability to provide additional dedicated point-to-point circuits reserved exclusively for particular user groups.

In addition to the standard GÉANT IP service which provides access to the shared European Internet Protocol (IP version 4 and version 6) research and academic network, GÉANT offers two distinct types of advanced international point-to-point network connection services: GÉANT Plus and GÉANT Lambda. GÉANT Plus's flexible service offers connections up to 100Gbps using Multi-Protocol Label Switching (MPLS) technology, while GÉANT Lambda offers dedicated, guaranteed network capacity at 10Gbps or 100Gbps.

This report provides a description of GÉANT's core advanced services and gives an update on their take-up in Year 2 of the GN3plus project, as well as an overview of the status of other newly implemented services. The characteristics of the GÉANT Plus and GÉANT Lambda core advanced services are described in Section 2.

Section 3 gives details of the new GÉANT Plus and GÉANT Lambda point-to-point circuits delivered during Year 2, as well as the total number of circuits in use at the end of the year. It shows the number of circuits in use by each project participant and also gives an update on the usage and status of GÉANT's other newly implemented services.

Section 5 gives information on recent and future network service developments, while Section 6 summarises the services' main achievements and plans for future improvements. Information on the projects that are the services' key users is provided in Appendix A. A map of the GÉANT Network is included in Appendix B.

2 Core Network Services

In addition to the standard GÉANT IP service which provides access to the shared European IP research and academic network, GÉANT offers National Research and Education Networks (NRENs) two international reliable and secure point-to-point connectivity services: GÉANT Plus and GÉANT Lambda.

The particular benefit of the GÉANT Plus service is that, once an NREN has physically connected its equipment to the GÉANT equipment for their IP service, each new individual point-to-point service has a short set-up lead time. Several such project connections can use the same port and each GÉANT Plus connection can be limited to a specific bandwidth at the NREN's request. In contrast the GÉANT Lambda service gives the advantage of dedicated 10GE, 100GE ports connected using guaranteed bandwidth over GÉANT's advanced transmission network.

The Layer 3 VPN Service (L3VPN) was finalised during the first year of GN3plus so that it is now part of the GÉANT services portfolio and can be ordered by any NREN.

2.1 GÉANT Plus Service

GÉANT Plus is available at all GÉANT Points of Presence, using the Juniper MX-series infrastructure. The GÉANT Plus service has the following characteristics:

- The standard physical interface at all GÉANT Points of Presence (PoPs) can be either 10GE or 100GE on Juniper MX-series routers.
- GÉANT Plus offers point-to-point Layer 2 connectivity over GÉANT IP infrastructure using Ethernet over MPLS. Circuits are delivered as VLANs on an NREN's access interface.
- Each service is built between two GÉANT router ports.
- Provided sufficient physical bandwidth is available, circuits can be implemented or reconfigured within 5 working days from the time an order is accepted and at no additional cost to the NREN.
- The GÉANT Plus service is considered part of the IP annual subscription, which includes as many GÉANT Plus connections as the NREN requires, provided the sum of the various GÉANT Plus circuits and the IP bandwidth do not exceed the NREN's total IP subscription.
- GÉANT Plus is delivered over the highly resilient IP network and, as such, offers extremely high availability:
  - 99.999% in the core backbone (which equates to 6 seconds per calendar year)
  - 99.7% (across GÉANT, including client interfaces).

- No bandwidth limitation is applied to GÉANT Plus circuits by default.
- GÉANT Plus services can be connected to equivalent services in non-GÉANT organisations, including some transatlantic destinations.

2.2 GÉANT Lambda Service

GÉANT Lambda circuits are offered between NRENs in Europe where it has been possible to procure the necessary network infrastructure, i.e. dark (unlit) fibre optic cables on which optical equipment is placed to light circuits that can be incrementally enabled as demand requires.

The GÉANT Lambda service has the following characteristics:

- The GÉANT Lambda service provides transparent connections with dedicated bandwidth of 10Gbps or 100Gbps between any NREN-facing ports at any two GÉANT PoPs on the dark fibre cloud.
- This service can be provided protected or unprotected. Protection can be provided either across the backbone only ("SNCP"), or as full protection i.e. with separate client interfaces.
- GÉANT Lambda services can be connected to equivalent services in non-GÉANT organisations, including some transatlantic destinations.
- A 10Gbps or 100Gbps Lambda takes up to 10 working days to establish if the physical infrastructure is in place, or up to 10 weeks if new hardware is required.
- The GÉANT Lambda service is provided on payment of an annual flat-rate fee for each connection deployed.
- For an unprotected lambda, the availability target is 99.5% up to 1000km, which is then reduced by 0.5% for every additional 1000km.

2.3 Layer 3 VPN Service

GÉANT's Layer 3 VPN Service (L3VPN) offers a solution for research projects that require the additional security and reassurance of a Virtual Private Network to ensure data services are isolated from general IP traffic. The service allocates unique VLAN identifiers to each L3VPN to ensure data isolation across the GÉANT network giving assured performance and security.

L3VPNs are also ideal for many-to-many (peer to peer) or one-to-many (central site to satellite) environments.

3 Use of Core Network Services in Year 2

3.1 GÉANT Plus and GÉANT Lambda Point-to-Point Circuits

26 new or upgraded point-to-point circuits were delivered in Year 2 of GN3plus, from 1 April 2014 to 31 March 2015, including 20 GÉANT Plus and 6 GÉANT Lambda circuits. This brings the total number of circuits in use at the end of Year 2 to 112 (80 GÉANT Plus/ L2 Services and 32 GÉANT Lambda circuits).

3.1.1 New GÉANT Plus Point-to-Point Circuits in Year 2

The following 20 GÉANT Plus circuits were delivered in Y2, compared to 14 in Y1 of the project. No bandwidth limitation is applied to GÉANT Plus circuits by default. On average, 15 VLANs are requested per GÉANT Plus service.

Project	A-End	B-End	Production Date
MD-VPN	Hungarnet	NIIFI PIONIER	Apr-14
Smart FIRE	RedIRIS	NORDUnet	May-14
Fed4FIRE	Belnet	RedIRIS	Jun-14
Fed4FIRE	Belnet	RedIRIS	Jun-14
Fed4FIRE	Belnet	RedIRIS	Jun-14
Fed4FIRE	Belnet	RedIRIS	Jun-14
Fed4FIRE	Belnet	RedIRIS	Jun-14
Fed4FIRE	Belnet	GRNET	Jun-14
OFELIA	Belnet	RedIRIS	Jun-14
Fed4FIRE	Belnet	RedIRIS	Jun-14
I2CAT	RedIRIS	CLARA	Jun-14
OKEANOS-XDC	GRNET	PIONIER	Jul-14
OKEANOS-XDC	GRNET	PIONIER	Jul-14
NREN-MISC	ESnet	UbuntuNet	Jul-14
NREN	Belnet	JANET	Oct-14
NREN	iMinds	Belnet	Feb-2015
NREN	iMinds	Belnet	Feb-2015
NREN	iMinds	Belnet	Feb-2015
NREN	JIVE SURFnet	PIONIER	Feb-2015
NREN	JANET	SURFnet	Mar-2015

Table 3.1: New GÉANT Plus circuits delivered in Year 2 at 31 March 2015

3.1.2 New GÉANT Lambda Point-to-Point Circuits in Year 2

Six new GÉANT Lambda circuits have been delivered since the last Service Uptake report. All GÉANT Lambda circuits are 10Gbps unless otherwise stated.

Project	A-End	B-End	Production Date
CESNET ANA	Amsterdam	Prague	March 2014
CESNET ANA	Amsterdam	Prague	March 2014
ESnet 100G	Geneva	London	October 2014
ESnet 100G	Amsterdam	London	October 2014
ESnet 100G	Amsterdam	Geneva	November 2014
DFN-CERN	Frankfurt	Geneva	January 2015

Table 3.2: New GÉANT Lambda circuits delivered in Year 2 at 31 March 2015

3.1.3 Total GÉANT Plus Point-to-Point Circuits in Use

At the end of Year 1, 48 GÉANT Plus circuits were in use. At the end of Y2 this has risen to 80, an increase of 66%. Table 3.3 shows the GÉANT Plus circuits in use broken down by project. The total shows all currently installed circuits.

Project	No of GÉANT Plus/Layer 2 circuits
EBI	1
e-VLBI	1
EXPReS	3
EYR3	1
Fed4FIRE	8
FEDERICA	5
Future Internet	1
GENI	2
GEYSERS	4
GN3plus-JRA1-T2	1
Grid 5000	2
HPDMnet	3
I2CAT	3
iMinds	1
JAXA	2
JIVE	1
LHC	1
MD-VPN	4

Project	No of GÉANT Plus/Layer 2 circuits
NIRAN	1
NISN-CNES	4
NREN-IX	3
NREN-MISC	1
OCX	1
OFELIA	4
OKEANOS-XDC	2
Openflow Testbed	10
PRACE	2
Smart FIRE	1
GTS	6
WIGNER	1
Total	**80**

Table 3.3: Number of operational GÉANT Plus circuits in use by each project at 31 March 2015

3.1.4 Total GÉANT Lambda Point-to-Point Circuits in Use

As at the end of Year 2, 32 GÉANT Lambda circuits are in use. Table 3.4 below shows the GÉANT Lambda circuits in use broken down by project. The total shows all currently installed circuits.

Project	No of GÉANT Lambda circuits
HEP	1
LHC	11
ESnet	3
PRACE	6
LOFAR	2
IX CESNET	1
GTS	6
NREN-MISC	2
Total	**32**

Table 3.4: Number of operational GÉANT Lambda circuits in use by each project at 31 March 2015

3.1.5 Total GÉANT Plus and GÉANT Lambda Point-to-Point Circuits in Use

Figure 3.1 below shows the number of circuits and the percentage of the combined total of both circuit types used by each project. The total of 112 circuits shown excludes any IP trunks between GÉANT backbone routers. All percentages are shown rounded up to an integer %. The largest users of the GÉANT core advanced services are Bandwidth on Demand (BoD) and the Large Hadron Collider (LHC) with 10% and 10%, all point-to-point circuits respectively. BoD is described in Section 4 and LHC in Section A.2.

Project	No. of Lir	% of Total Links
DEISA / PRACE	6	5%
EBI	1	1%
Esnet	3	3%
e-VLBI	1	1%
EXPReS	3	3%
EYR3	1	1%
Fed4FIRE	8	7%
FEDERICA	5	4%
Future Internet	1	1%
GENI	2	2%
GEYSERS	4	4%
GN3plus-JRA1-T2	1	1%
Grid 5000	2	2%
HEP	1	1%
HPDMnet	3	3%
I2CAT	3	3%
iMinds	1	1%
JAXA	2	2%
JIVE	1	1%
LHC	12	11%
LOFAR	2	2%
MD-VPN	4	4%
NIRAN	1	1%
NISN-CNES	4	4%
NREN-IX	4	4%
NREN-MISC	3	3%
OCX	1	1%
OFELIA	4	4%
OKEANOS-XDC	2	2%
Openflow Testbed	10	9%
PRACE	2	2%
Smart FIRE	1	1%
TaaS/GTS	12	11%
WIGNER	1	1%
Total	112	

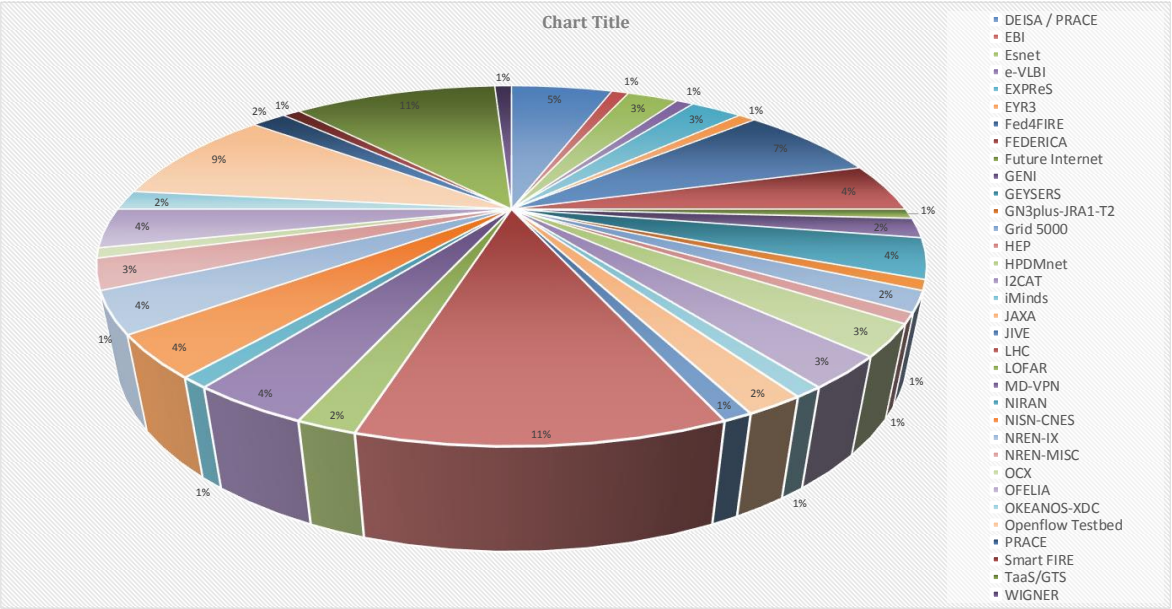

Figure 3.1: Total number of GÉANT Plus and GÉANT Lambda circuits and percentage of the combined total of both circuit types used by each project at 31 March 2015

Note: The project name "NREN-IX" denotes an NREN–Internet Exchange (IX) circuit, which connects a specific NREN to a specific commercial Internet Exchange.

3.2 L3VPN Service Connection Points

By the end of Y2 this service has been taken up by 15 NRENs/REs and 30 L3VPN service connection points are now in place. 12 L3VPNs were commissioned during Y2.

The LHCOPN, connecting CERN and Tier 1 sites together for the Large Hadron Collider Optical Private Network, has traditionally made use of the GÉANT Lambda and GÉANT Plus services. The requirements of the new LHC Open Network Environment (LHCONE) influenced the service design of the L3VPN service, LHCONE. The LHCONE L3VPN currently interconnects CERN, with European NRENs and 5 International RE partners and transports approximately 30Gbps of peak traffic.

The LHCONE is the biggest L3VPN user with 15 connected project participants, giving the LHC community their own private network. LHCONE is designed to connect the LHC Tier 1 and Tier 2 sites using Border Gateway Protocol / Multi-Protocol Label Switching technologies.

NREN/RE	Project	No of GÉANT L3VPN
ARNES	LHCONE	2
ASGC NOC	LHCONE	1
CANARIE	LHCONE	2
CERN	LHCONE	1
CESNET	LHCONE	1
DFN	LHCONE	2
DFN	CONFINE	1
ESnet	LHCONE	5
GARR	LHCONE	2
Internet2	LHCONE	3
NORDUnet	LHCONE	2
RedIRIS	LHCONE	1
RedIRIS	CONFINE	1
RENATER	LHCONE	2
RoEduNet	LHCONE	1
SINET	LHCONE	2
SURFnet	LHCONE	1

Table 3.5: Number of Layer 3 VPN connections by NREN and project

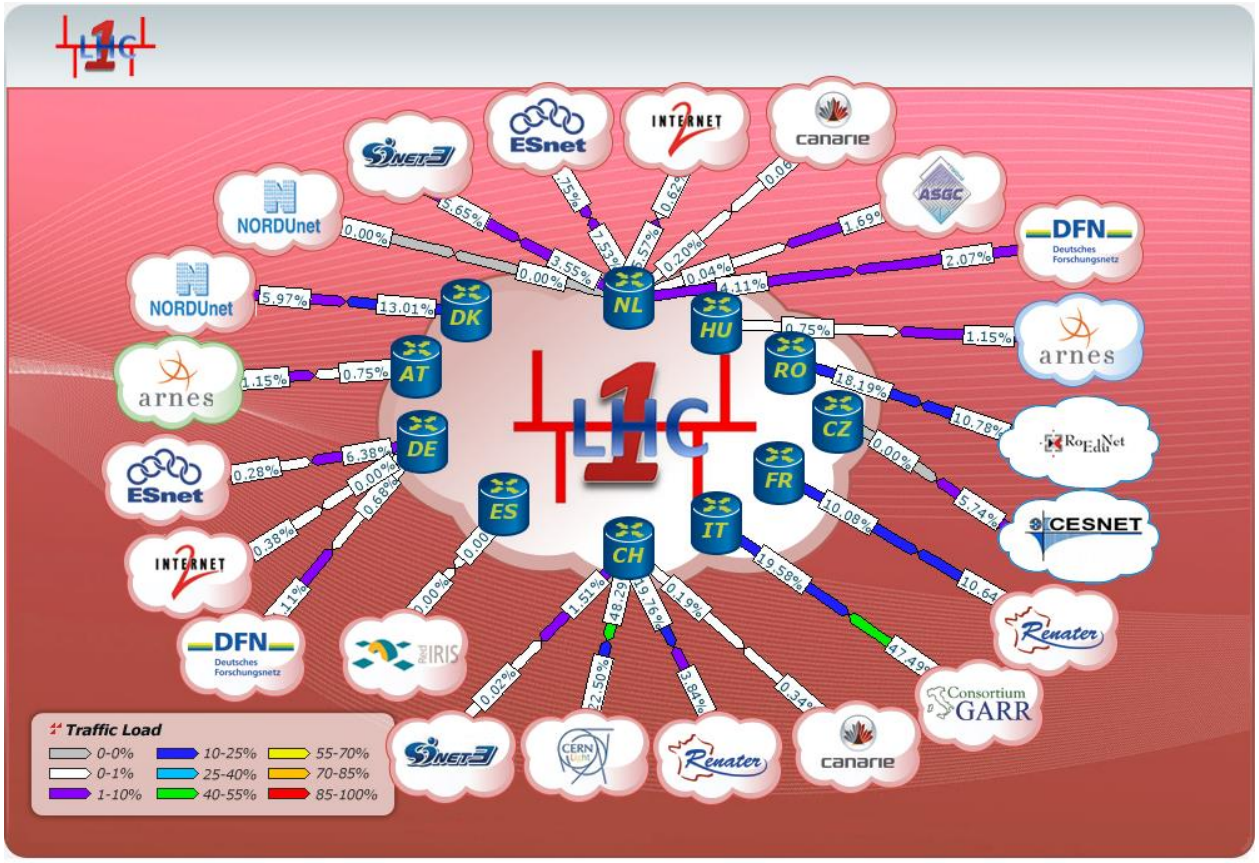

Figure 3.2: LHCONE topology with circuit utilisation

4 Bandwidth on Demand

Co-provisioned by GÉANT and participating NRENs, GÉANT Bandwidth on Demand [BoD] is a service for dynamic bandwidth provisioning across multiple networks, enabling users to instantly create dynamic point-to-point circuits through a web-based user interface.

Following an extensive pilot carried out with NRENs across Europe, including CARNet (Croatia), DeiC (Denmark), GRNET (Greece), HEAnet (Ireland), Janet (UK), NORDUnet (Nordics), PIONIER (Poland) and SURFnet (Netherlands). The pilot was run in collaboration with US research networks ESnet and Internet2 in order to ensure compatibility and enable the provision of transatlantic circuits.

The service's end-users can access the Bandwidth on Demand service and set up circuits dynamically, either through a web portal or through their own applications (using an API). Previously, end-users of the service were mostly those involved in "big science" – such as radio-astronomy or high energy physics – or "network technologists", for whom network innovation was a key element of their research, such as cloud, virtualisation or Future Internet initiatives. However, in 2013, the project also engaged in dialogue with new types of users representing smaller-scale projects in physics, the arts (eMusic), or new fields such as bioinformatics.

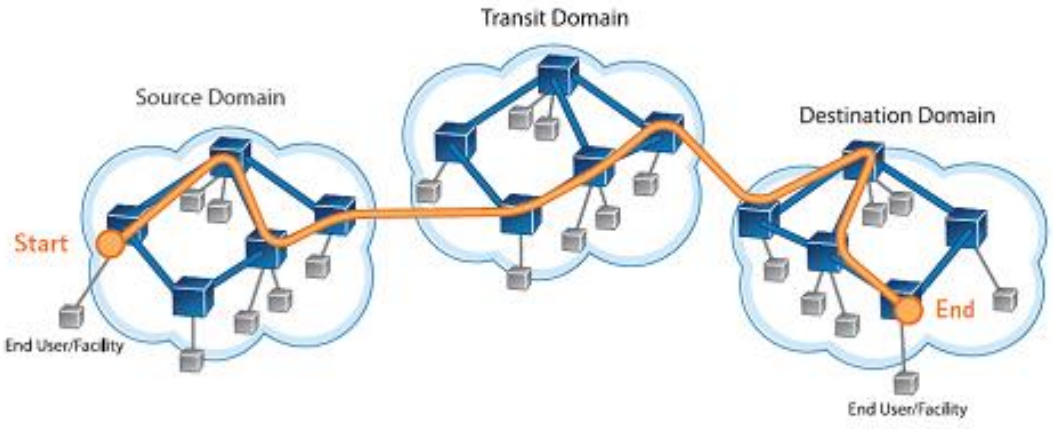

Figure 4.1: End to End BoD Service

Service requests can be managed directly by the user through a web browser or through other client applications such as OpenNaaS. If an NREN decides to use GÉANT's AutoBAHN provisioning tool, they

will have access to the "BoD Client Portal", a web-based user interface designed to make the reservation, ordering and management processes efficient and intuitive.

Figure 4.2: BoD Locations

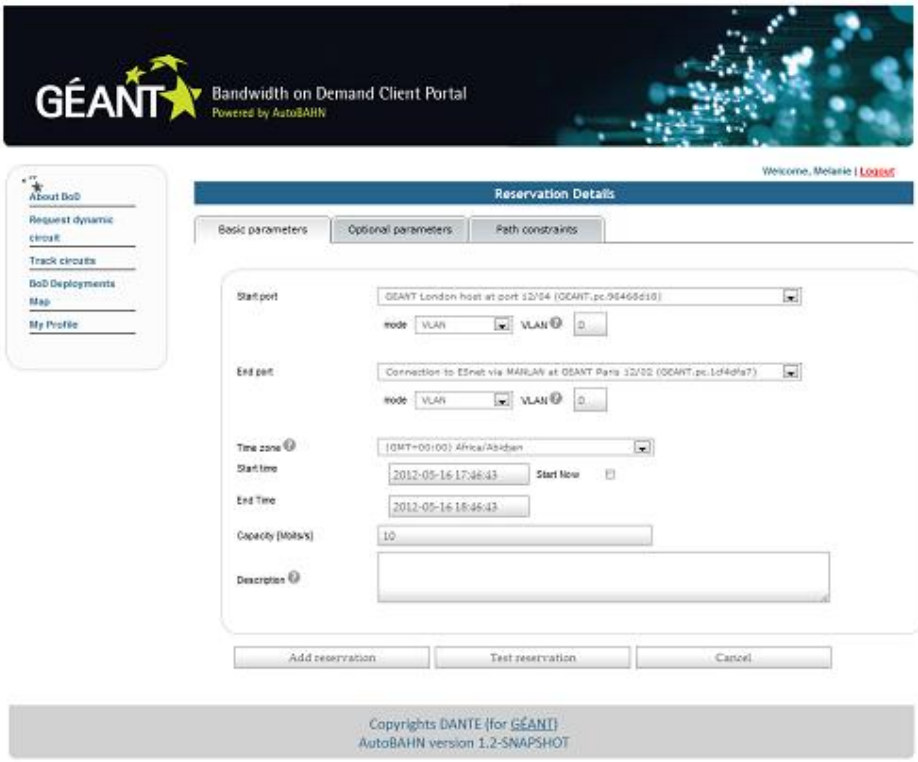

Figure 4.3: Autobahn "BoD Client Portal"

5 Recent and Future Service Developments

The reach of the GÉANT Plus service is continually expanding to provide connectivity for more organisations in a growing number of countries.

The integration of the GÉANT Plus and IP networks into one set of Juniper MX routers in the GÉANT network has brought about a greater degree of stability and ease of support, particularly with regards to the ability to support 100Gbps connections from NREN equipment to GÉANT routers for IP service and GÉANT Plus connections.

The upgraded transmission network enables the provision of 10Gbps and 100Gbps GÉANT Lambda services at a greatly reduced lead time compared to previous years, so that the lead time for 10Gbps connections, for instance, has been reduced from the previously required 15 weeks, to just ten days.

A map of the current GÉANT network is provided in Appendix B, while a more detailed description of GÉANT's services can be found in the Service Catalogue on the Partner Portal [GEANTServiceCatalogue].

5.1 GÉANT Open Service

In addition to the services mentioned above, the new GÉANT Open service [GEANTOpen] has progressed beyond the pilot phase and is now in production. The service allows research users to connect to ports at 100Gbps, 10Gbps or 1Gbps, and to then request interconnections with any other participant in order to provide point-to-point layer 2 connectivity. To date, the following partners and projects are currently connected or have requested connections to GÉANT Open:

- NORDUnet
- SURFnet
- ACE
- Internet2
- ORIENT plus
- GÉANT

5.2 Multi-Domain Virtual Private Network Service

The Multi-Domain Virtual Private Network (MDVPN) [D7.1_DS3.3.1] service is currently running in a pilot phase with nine RE networks (including GÉANT and NORDUnet). These features were demonstrated to be supported by commonly used routing equipment without requiring additional hardware investment. MDVPN, which is an umbrella service, will offer Point-to-Point VPNs at OSI Layer 2 and Multi-point VPNs at both Layer 2 and Layer 3 to 16 RE networks (including GÉANT and NORDUnet). GÉANT and NORDUnet play a specific role in the architecture, as they transport the underlying VPN using Carriers' Carrier technology, rather than delivering the service directly to the end-user. At present 17 NREN are connected to MD-VPN and one large project, XIFI (a part of the Public-Private-Partnership on the future Internet (FI-PPP) of FP7) and there are 457 PE (BGP route announces) in place

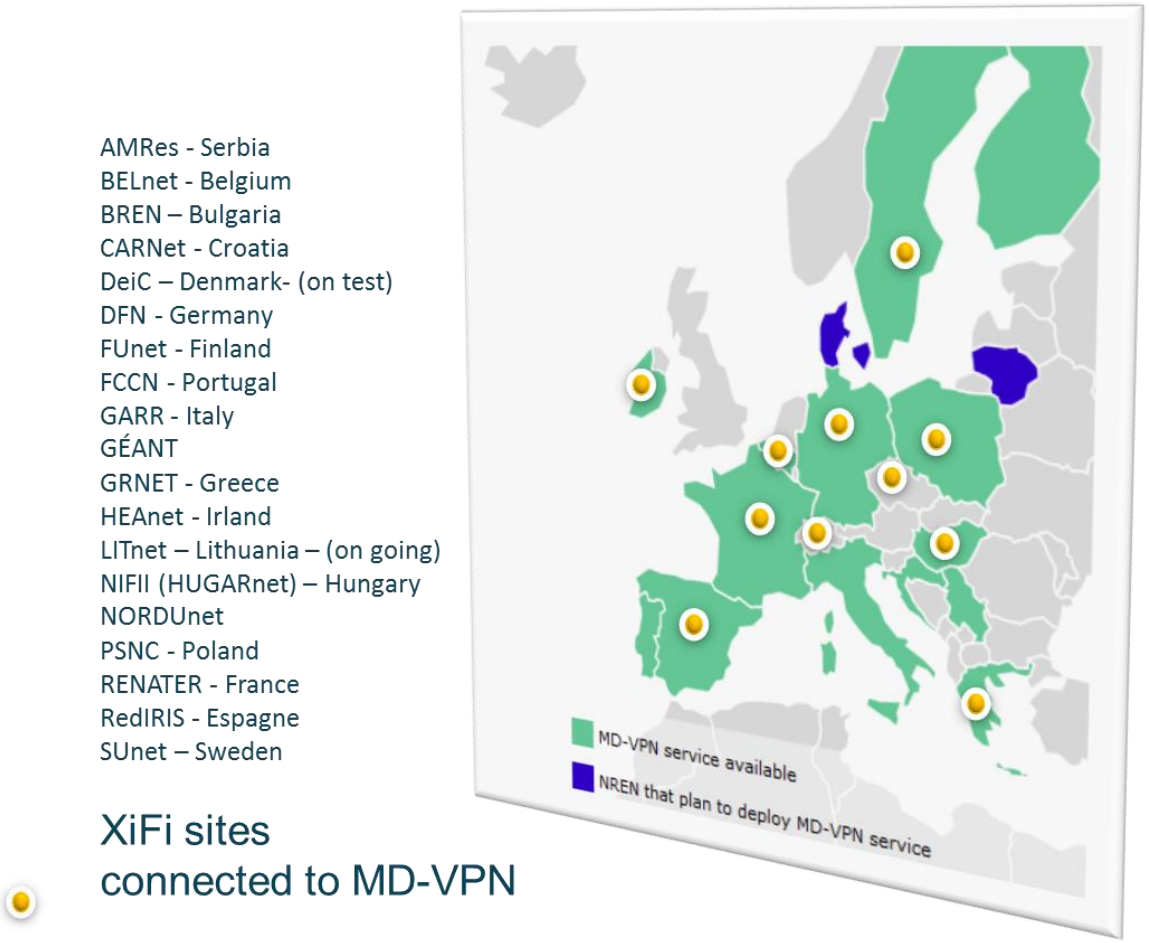

Figure 5. 1: MD-VPN and XIFI Participants

6 Conclusions

GÉANT is an international hybrid network that combines the operation of a shared IP infrastructure with the additional capacity to provide dedicated point-to-point circuits. The network has been designed to offer the greatest flexibility and as such provides three different levels of connectivity services.

Both its core advanced services, GÉANT Plus and GÉANT Lambda, and its new services, provide levels of privacy, security, availability, capacity, robustness and speed to meet the requirements of even the most demanding user projects.

Utilisation of GÉANT point-to-point services remains high and several new circuit requests have been received, with 58 new circuits delivered in Year 2.

Following its successful pilot, GÉANT Open is now a full production service and Y2 four new 100Gbps connections were added (NORDUnet, SURFnet, ESnet, and Internet2) were added to GÉANT Open.

Building on the experience gained in recent years, a process of continuous improvement and cost savings is underway with further to developments to enhance the design, implementation and incident management procedures of GÉANT's advanced services.

Appendix A Projects

A.1 Projects Using GÉANT Connectivity Services

Table A.1 below lists the projects that use and/or are supported by GÉANT advanced services.

Project	URL
DEISA/PRACE	http://www.deisa.eu and http://www.prace-ri.eu/
EBI	www.ebi.ac.uk/
e-VLBI	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/
GN3 JRA T4	http://www.geysers.eu/
GreenStar Network / GSN	http://www.greenstarnetwork.com/
LHCONE	http://www.geant.net/Users/Particle-Physics/Pages/LHCONE.aspx
HPDMnet	http://www.hpdmnet.net/
i2CAT	http://www.i2cat.net/en
iMinds	www.iminds.be/en
JIVE	http://www.jive.nl/about-jive
LHCOPN	http://public.web.cern.ch/public/en/LHC/LHC-en.html
LOFAR	http://www.lofar.org/
OFELIA	http://www.fp7-ofelia.eu/
WIGNER	http://wigner.mta.hu/wignerdc/

Table A.1: Websites for Projects using GÉANT advanced services

A.2 LHC

The largest user in terms of numbers of GÉANT point-to-point circuits is the Large Hadron Collider [LHC], 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 they could not be funded by any single state.

The LHC project involves the acceleration of particles to previously impossible energies, producing short-lived results that have never been obtained before. It has already produced several Petabytes (several million Gigabytes) of data. It was decided that all this data should not be processed by a single institution, but rather using a grid – the Worldwide LHC Computer Grid (WLCG) – so that the results will be distributed by GÉANT and connected NRENs to analysis sites around the globe using LHCOPN and LHCONE.

Appendix B GÉANT Topology

The diagram below shows a map of GÉANT leased wavelengths and Dark Fibre. The Dark Fibre is lit using GÉANT Infinera equipment and leased wavelengths are provided with Ethernet WAN-PHY technology i.e. transported over providers' SDH circuits.

At the time of writing, several leased wavelengths are in the process of being replaced, with the new replacement wavelengths and the old wavelengths previously leased from other providers running in parallel for the duration of the notice period for the latter. Such temporary duplicates are not shown here, with the exception of Luxembourg – Paris, which is being replaced with a Luxembourg – Amsterdam circuit.

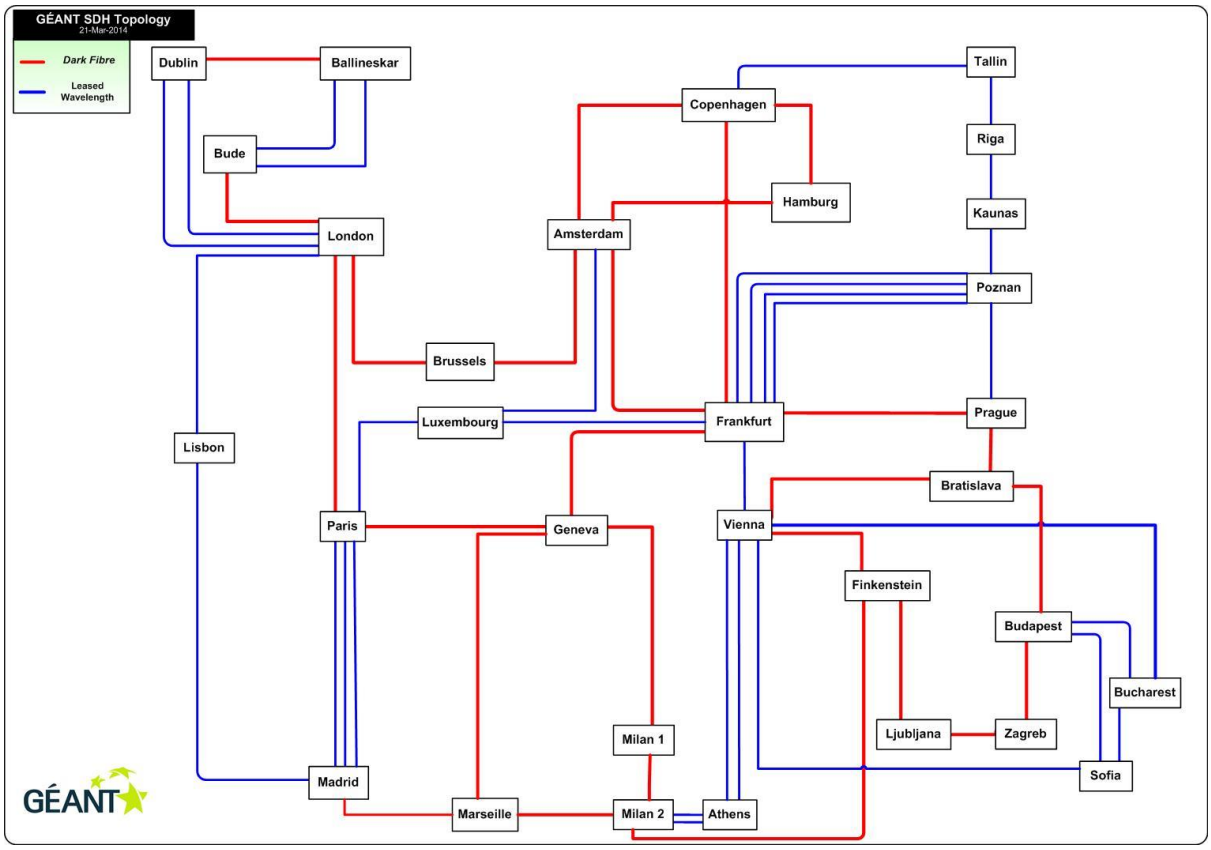

Figure B.1: GÉANT topology at 31 March 2015

References

[AutoBAHN]	https://forge.geant.net/forge/display/autobahn/Home
[BoD]	http://services.geant.net/bod/Pages/Home.aspx
[CONFINE]	http://confine-project.eu
[D7.1_DS3.3.1]	D7.1 (DS3.3.1): MDVPN Service Architecture http://www.geant.net/Resources/Deliverables/Documents/D7.1_DS%203%203%201-MDVPN-service-architecture.pdf
[DEISA]	http://www.deisa.eu
[PRACE]	http://www.prace-ri.eu/
[FEDERICA]	http://www.fp7-federica.eu
[LHC]	http://public.web.cern.ch/public/en/LHC/LHC-en.html
[GÉANT Open]	http://www.geant.net/Services/ConnectivityServices/Pages/GEANTOpen.aspx
[GÉANT Service Catalogue]	https://partner.geant.net/Service_Catalogue
[GENUS]	https://tnc2011.terena.org/getfile/187
[NSI v1.0]	http://www.ogf.org/documents/GFD.173.pdf
[NSI v1.1]	https://redmine.ogf.org/dmsf_files/9992
[NSI v2.0]	http://redmine.ogf.org/boards/18/topics/241

Glossary

AAI	Authentication and Authorisation Infrastructure
ACE	America Connects to Europe
AMS-IX	AMSterdam Internet eXchange
BoD	Bandwidth on Demand
Carriers' Carrier	VPN technique described in RFC4364, aka 'Carrier Supporting Carrier' (Cisco) and 'Carrier of Carriers' (Juniper)
CERN	European Organisation for Nuclear Research
DEISA	Distributed European Infrastructure for Supercomputing Applications
DWDM	Dense Wavelength-Division Multiplexing
EGEE	Enabling Grids for E-scienceE
e-VLBI	Consortium for Very Long Baseline Interferometry in Europe
EXPReS	Express Production Real-time e-VLBI Service
FEDERICA	Federated E-infrastructure Dedicated to European Researchers
GENUS	GÉANT virtualization service
GEYSERS	Generalised Architecture for Dynamic Infrastructure Services
GSN	GreenStar Network
IP	Internet Protocol
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
LINX	London INternet eXchange
LOFAR	LOw Frequency Array
MDVPN	Multi-Domain Virtual Private Network
MPVPN	Multi-Point Virtual Private Network
MPLS	Multi-Protocol Label Switching
NOC	Network Operations Centre
NOVI	Networking innovations Over Virtualised Infrastructures
NREN	National Research and Education Network
NSI	Network Service Interface
OFELIA	OpenFlow in Europe, Linking Infrastructure and Applications
VPN	Virtual Private Network
WIGNER	Wigner Research Centre for Physics, Budapest, Hungary – CERN data centre
WLCG	Worldwide LHC Computer Grid