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Deliverable DS1.1.1: Report on Backbone Architecture Study

Interim Report on Architecture Workshop Process

Deliverable DS1.1.1

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Abstract

This deliverable reports on the initial results of the backbone architecture study, as represented by the outcome of a series of Architecture Workshops, and on the supporting capacity planning exercise and Internet Exchange analysis.

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Executive Summary

The future architectural developments of GN3 have been explored in a series of workshops looking at many facets of the technology, resources costs and operations. The workshops were intended as a major input to the work of Service Activity SA1, Network Build and Operations, and in particular to the participants of Task 1 of that activity (Network Planning and Procurement Preparation). This document describes the progress made in the workshops, the key findings achieved as well as supporting work such as capacity planning. It is recognised that there are still a significant number of knowledge gaps that need filling before any decisions can be made on detailed architectural choices. Much of the detailed work required to address these gaps is now underway. This document therefore provides an interim report, based on the outcome of the workshops; an update documenting the detailed work and the architecture decisions resulting from it is envisaged around month 18 of the project (September 30, 2010).

Section 1 of this report gives a brief introduction to the work of SA1 Task 1, Network Planning and Procurement Preparation. Section 2 outlines the approach taken by SA1 T1, focusing on the inputs or requirements the Task needs to consider. Section 3 provides an overview of the five Architecture Workshops whose discussions have fed into SA1 T1, covering the agendas and a summary of their conclusions. Section 4 describes the capacity planning exercise, another key input, including its scope, method (i.e. by questionnaire, a template of which is attached as Appendix A on page 26), results and an analysis of the potential impact on the GÉANT backbone. Finally, Section 5 summarises the status of SA1 T1 and presents an outline of the work plan for the remaining architecture phase of the GÉANT backbone.

The key inputs to SA1 T1 include services to be supported by the backbone; knowledge of existing and upcoming transmission infrastructures; consortium expansion plans; capacity forecasts; total cost of ownership (TCO) studies; findings from GN3 technology assessment activities; plans for global connectivity; results of network and service resilience studies; and savings of energy consumption and space usage.

The five architecture workshops have served as the means to discuss many issues that are relevant to the future GÉANT network architecture. Topics include network service requirements and predictions; technologies; cost issues, particularly surrounding use of cross-border fibre (CBF) and establishing Internet Exchange (IX) peering; network operations; the digital divide; and global connectivity. Amongst the key findings and conclusions to emerge from the workshops were the predicted timing of requirements for 100 Gbps, the use of technologies such as Carrier Ethernet EoMPLS and Optical Transport Network (OTN) to support the GÉANT Plus service, and the need to identify and evaluate where resources offered by NRENs (CBF) can be integrated into the network where it makes technical and economic sense to do so. The findings have formed the basis for identifying a roadmap for GÉANT architecture planning, which is described in Section 5.

Periodically DANTE performs surveys in which it solicits input on future backbone network service requirements from all of the GÉANT NRENs. The last of these was a questionnaire distributed to the NRENs at the end of 2008 seeking input on their expectations for GÉANT capacity usage throughout the period of the GN3 project. Topics covered included IP traffic bandwidth requirements ("R&D" transit to European and international RENs); IP traffic bandwidth requirements ("commodity" traffic to/from providers of global upstream IP service, excluding that to/from national peering partners); sub-wavelength point-to-point circuit requirements (e.g. GÉANT Plus); full wavelength point-to-point circuit requirements (e.g. GÉANT Lambda); new services. The initial projected demand forecasts showed that some 40 Gbps transmission capability on the GÉANT backbone will be needed in 2010 and that 100 Gbps transmission capability on the GÉANT backbone might be needed from the end of 2011/start of 2012. If retained, the current GÉANT DWDM transmission platform will need to undergo upgrades to become capable of delivering these capacities (mainly to the network management software and some hardware upgrades across the transmission platform). Further work is needed to refine these projections and the design rules used for planning upgrades to the network.

At the time of writing (March 2010), some significant pieces of analysis have been completed but quite a few more are needed before sufficient information will be available to bring together an overall vision of the architectural goals upon which the GÉANT network architecture can be based. This will include looking into layers 1, 2 and 3 of the GÉANT architecture and deriving a set of recommendations to be approved at GN3 Executive and NREN PC level. Taking into account the current contractual commitments, including the expiration of some supply contracts that will need to be extended or replaced according to EU procurement regulations, a mapping from what currently exists to the future vision will be required to allow a phased procurement, rollout and operating phase.

The GN3 Executive has established a GÉANT Architecture Committee, chaired by Ivan Maric (E.-J. Bos Co-Chair), which accompanies the SA1 work and which reports directly to the Executive Committee.

This report gives a snapshot of the work involved in the architectural design of GÉANT, identifying what has been achieved to date and what will be completed in the coming months.

1 Introduction

Detailed studies of the development of the GÉANT backbone architecture within the first 2 years of the GN3 project are being conducted within SA1 Task 1. Alongside this and feeding into it have been a series of "architectural workshops" which were intended to address, at a higher level, a number of relevant topics including technologies, service innovation, operational aspects, novel infrastructure and manpower resourcing scenarios and some policy-related aspects. Although a set of documents summarising the discussions and conclusions of these workshops has been produced within the internal project literature, a summary is included in this document and can be found in Section 3, "Architecture Workshops" on page 7.

SA1 Task 1 envisages taking a number of inputs such as service requirements (both types and volumes), advice on state-of-the-art network transport technologies, strategic directions and expansion plans and producing a project-approved blueprint for the upgrade of the GÉANT backbone to be undertaken during the lifetime of the GN3 project. This blueprint will, in the shorter term, lead to the creation of a procurement timetable that will be used by the procurement team working in SA1 Task 2.

At the time of writing (March 2010), some of the work necessary to complete this task has already been completed and other aspects are just getting underway. This document, therefore, provides an interim report, based on the outcome of the workshops and giving the status of all this work; a further update is envisaged around month 18 of the project.

The report is structured as follows:

- The next section, Section 2, outlines the approach taken by SA1 Task 1, focusing on the inputs or requirements the Task needs to consider.
- Section 3 provides an overview of the five Architecture Workshops, covering the agendas and a summary of their conclusions.
- Section 4 describes the capacity planning exercise, including its scope, method (i.e. by questionnaire, a template of which is attached as Appendix A on page 26) and results. It analyses the potential impact on the GÉANT backbone, checks the capacity estimates against the original forecast and draws conclusions.
- Section 5 summarises the status of SA1 T1 and presents a work plan for the remaining sub-tasks and milestones of the architecture phase of the GÉANT backbone.

2 Approach

The scope of the SA1 Task 1 work is illustrated in Figure 2.1 below.

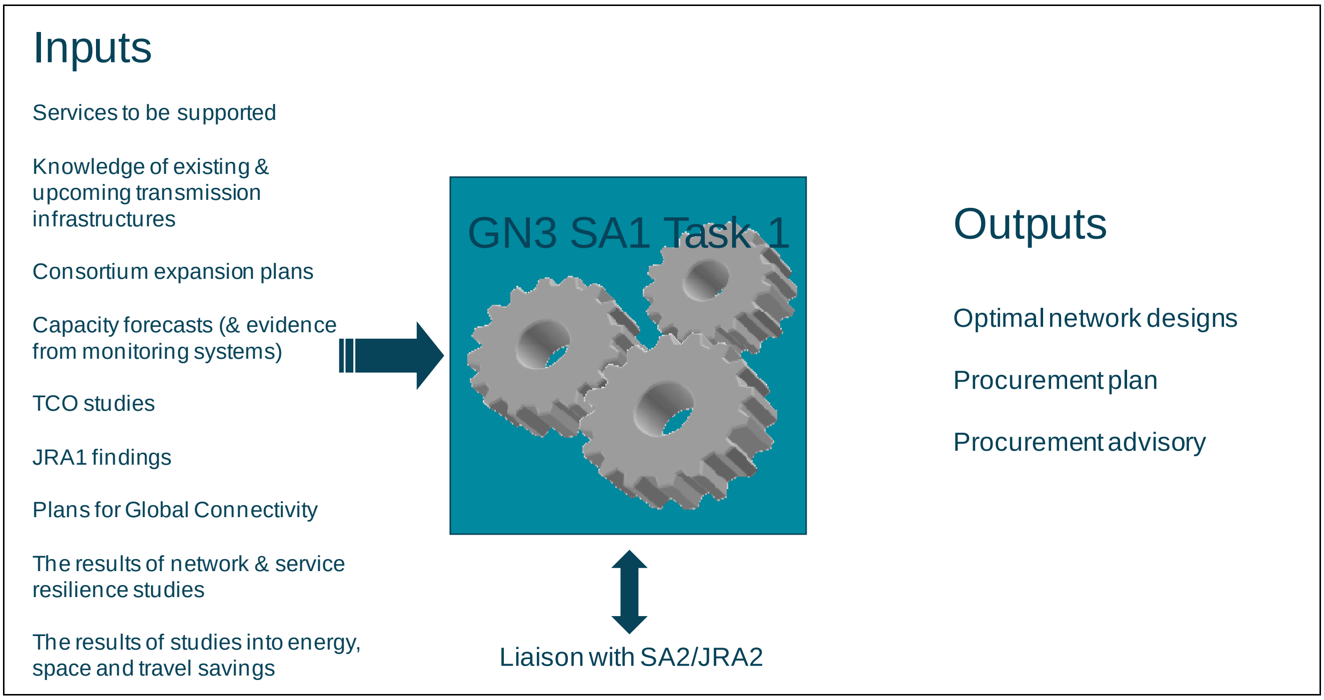

Figure 2.1: Illustration of scope of SA1 Task 1

The task clearly needs to consider a number of requirements and these are further discussed below.

Services to be supported (by the backbone)

This has clearly to be based on a broadly accepted expectation of the stakeholders in the GÉANT backbone concerning the service capabilities that the backbone can reasonably be expected to support at various points throughout the lifetime of the GN3 project and beyond. This, in turn, should be based on a number of component secondary requirements:

- A target portfolio of **end-user** services that can reasonably be expected to be made available across a significant part of the extended GÉANT service area (that including the GÉANT backbone and the NRENs) within the lifetime of the GN3 project and beyond.

- A target portfolio of **backbone transit** services that DANTE can reasonably be expected to make available to the majority of the NRENs within the lifetime of the GN3 project.
- Expectations that the backbone should, to some extent, be at the technological “cutting edge” and therefore be an infrastructure that is a relatively “early adopter” of newer network technologies (e.g. 100Gbps transmission).

Definitive statements on these have not really been established up to the time of writing – mainly because accurate forecasting of service requirements in the medium to longer terms (more than two years away) are very difficult per se and uncertainties over potential cost implications are often a barrier to strong assertions on long-term strategic ambitions.

In order to help in efforts to overcome this impasse, a set of potential GÉANT backbone service portfolio enhancements have been drawn up within SA1 Task 1 and socialised in the wider GÉANT community – e.g. in the architecture workshops and amongst the GÉANT NREN Access Port Managers (APMs). This is now intended to be at the centre of information-gathering activities targeting the suppliers of network transport equipment that, at the time of writing, are getting underway. More details on this set of service enhancement proposals can be found in a dedicated GN3 document [BbSvcProposal].

Knowledge of existing and upcoming transmission infrastructures

This will be based on the findings of “pre-procurement” investigations wherein studies are conducted of the operator marketplace in particular regions of the GÉANT service area (and regions in which the GÉANT service area is expected to be expanded). Where possible, this will include detailed analysis of the underlying physical infrastructures and assessments on the likelihood of members of the GÉANT consortium (DANTE or the relevant NRENs) being able to get affordable access to this infrastructure. An example of such pre-procurement study can be found in a short report that was written on the provider market in the Balkan region (within the context of a short-term requirement to extend GÉANT service to the NRENs of Serbia, Montenegro and FYROM) [Pre-ProcurementAnalysis]. There will be a particular focus in the next round of pre-procurement study on the desire to get access to fibre infrastructure in the same region with the intention of extending the GÉANT fibre footprint through the Balkan region (and Romania) to Greece and Turkey.

Connecting new members to the consortium

New members (NRENs of Serbia, Montenegro and FYROM) that have joined the GN3 project are already connected via legacy services and now recent procurements under the GN3 project have resulted in leased services being contracted to connect to them. Further work is needed to establish the efficient long-term architectural design and whether to establish PoPs in these locations.

Capacity forecasts (and evidence from monitoring systems)

As mentioned above, these are always difficult to compile with any accuracy. Nevertheless, a survey of NREN expectations was conducted at the end of 2008. This covered the GÉANT IP, GÉANT Plus and GÉANT Lambda services. Indications at that time (as reported in the second of the architecture workshops) were that the ability of the current GÉANT DWDM transmission platform to support the potential sum total of the capacity requirements without any interim upgrade (e.g. to support 40 Gbps wavelengths) was marginal in the busiest parts of the network (e.g. on the Frankfurt-Geneva trunk). Since then it has been possible to check up on the validity of some of the original predictions (at the end of 2009). More details of this analysis can be found in Section 4 “Capacity Planning Exercise” on page 12.

Studies of the total cost of ownership of various technical solutions

Making initial estimates of the total cost of ownership (TCO) of the various technical solutions that can be considered before entering formal procurement proceedings will necessarily require some initial budgetary input. This should be done in the preliminary evaluation of all potential implementation solutions that can then be considered as part of any resulting procurement phase.

Findings from GN3 technology assessment activities

JRA1 is performing various pieces of technology-focused analysis and assessment work. The findings from these will feed into other GN3 activities – especially those relating to service and service delivery platform design and procurement.

Plans for global connectivity

This has a bearing due to the capacities and forms of connectivity that will be established with R&E networks in other parts of the world (outside of the GÉANT service area).

The results of network and service resilience studies

Backbone network resilience studies will focus on gaining a better understanding of detailed underlying fibre routing and where shared infrastructure risks exist with that of NRENs and commercial providers. Such investigations proved to be particularly useful in studying the true resilience of the LHC OPN solution (taking into account all the connectivity provided by DANTE, NRENs and commercial providers).

Savings of energy consumption and space usage

The majority of the studies within the GN3 project into energy consumption by the European R&E networking community and their infrastructures and how savings might be realised are being conducted as part of NA3 Task 5. At the same time, the technology-focused analysis going on in JRA1 will pay attention to environmental efficiency factors. Together, this will provide useful input to the SA1 tasks 1 and 2.

Usage of floor space in hosting facilities is also increasingly important. GÉANT PoPs are often in neutral collocation facilities and the better connected of these are tending to get filled up. Accordingly, collocation space in these locations into which GÉANT PoPs could expand is increasingly in short supply (and hence getting more expensive) or not available at all.

3 Architecture Workshops

3.1 Introduction

The five Architecture Workshops have served as the means to discuss many issues that are relevant to the future GÉANT network architecture. Amongst the key points emerging from the workshops were the potential requirements for 100 Gbps, the use of technologies such as Carrier Ethernet EoMPLS and Optical Transport Network (OTN) to support the GÉANT Plus service, and the need to identify and evaluate where resources offered by NRENs (CBF) can be integrated into the network where it makes technical and economic sense to do so. (The terms of reference for the workshops are defined in [AW-TOR].)

3.2 Workshop Agendas

3.2.1 Fifth Workshop

The fifth and most recent workshop, held in Berlin on 20 January 2010, focused on overview presentations and discussions of:

- Architecture Workshop conclusions and roadmap for GÉANT architecture planning.
- GÉANT backbone services enhancements to investigate.
- SA1 work plan details.

3.2.2 Fourth Workshop

The fourth workshop was held in Rome on 19-20 October 2009 and focused on:

- An overview of NREN resources that could be made available to GÉANT, together with an overview of the associated administrative and organisational issues. Presentation of practical NREN experiences in sharing network resources from members.
- The proposed network connectivity services portfolio development and an overview of the technologies and network architectures that support it.

3.2.3 Third Workshop

The third workshop was held in Brussels on 7-8 July 2009 and focused on:

- An in-depth analysis of commodity IP traffic coming from NRENs and access to Internet Exchange Points (IXPs).
- Digital Divide – how it affects NRENs and what can be done to address the issues as seen by the affected NRENs.
- An overview of Global Connectivity, current and planned, and purpose of connections.

3.2.4 Second Workshop

The emphasis of the 2nd workshop, held in Brussels on 30 March-1 April 2009, was on:

- Analysis of predicted NREN connectivity requirements and technology options to fulfill those needs.
- Starting an investigation into multi-domain operations (workflows and sharing of NREN resources).
- Exploring possible ways of reducing the cost of commodity IP for NRENs.

3.2.5 First Workshop

The first workshop was held in Cambridge on 10-11 December 2008 and focused on:

- An overview of current GÉANT services, technologies, operations and costs of the current network.
- Presentation of experiences from NRENs on working with GÉANT.
- Participants' views on the issues to address for the future GÉANT.

3.3 Summary of Conclusions

The conclusions outlined below are drawn from a combined analysis of the summaries of the first to fourth workshops, as discussed at the fifth workshop.

3.3.1 Network Services

IP and circuit services are needed throughout the lifetime of GN3 and beyond, a requirement confirmed by the responses to a capacity planning questionnaire issued to all NRENs. Predictions for IP traffic growth on the current links of the GÉANT backbone emphasised that there is a potential need for 100 Gbps on a number of routes. According to the initial traffic projections, this could be before the end of 2011. They also identified a need to consider the implications of multi-10 Gbps paths during 2010/2011.

The need for circuit services was confirmed and the number of circuits used is predicted to grow at a rate of roughly 50% per annum. In the case of GÉANT Lambda services, there appears to be continuing demand for 10 G lambdas; some NRENs predict the requirement for 40 G lambdas, with limited forecast demand for 100 G lambdas.

The three service offerings – GÉANT IP, and the point-to-point services GÉANT Lambda and GÉANT Plus – are all predicted to grow at 50% per annum. This represents the aggregate/average growth of all NREN requirements.

At the fourth workshop, a discussion was held on the development of network services. This was based on input received at previous workshops and on the work of the SA1 Task 1 team. The network services will be the basis of the work to identify the best technology and network architecture for GÉANT.

3.3.2 Technologies

Over the course of the four workshops, technology discussions have reached the following conclusions:

- 40 Gbps is a relatively mature technology and there is scope for its deployment in the GÉANT backbone and on NREN access circuits, mainly as a stopgap measure until 100 Gbps is available.
- 100 Gbps is under development within the relevant standards bodies and by vendors. There is optimism that standardised 100 Gbps technologies will become available for deployment in early 2011.
- For the implementation of GÉANT Plus services, alternative techniques to the current NG-SDH technology should be sought, such as Carrier Ethernet EoMPLS and OTN. In the fourth workshop, it was recommended that NG-SDH technology be discontinued for delivering and accessing GÉANT Plus services, a recommendation that will be taken into account in developing the backbone architecture.
- The first workshop stressed the importance of the provision of virtual private networks (virtualisation), an assessment that will be taken into account in developing the backbone architecture.
- In the fourth workshop, an overview of WSS (Wavelength Selective Switching) technology was given. This technology may have potential in the GÉANT environment and requires some further investigation, which is being carried out within JRA1 and SA1 Task 1.

These technology topics are part of the work plans of GN3 SA1, SA2, JRA1 and JRA2 and will be continued there. The work of these activities will be coordinated in order to draw timely conclusions for the architecture of GÉANT and resulting procurements. The latter work will be conducted by the SA1 Task 1 team.

3.3.3 Cost Issues: Cross-Border Fibre and Internet Exchange Peering

This topic was discussed at length and from different perspectives. It is clear that reductions in the cost to the project of delivering network services must be sought in every possible way. Conclusions drawn are:

- Annual re-tendering of leased circuits, which, at more than 50% of the total GÉANT network costs, are by far the biggest single cost item in the GÉANT network and which currently have a high price due to (uncompetitive) market conditions, will be undertaken.

- A cost comparison of leased circuits, acquisition of fibre and CBF solutions on applicable routes must be conducted.
- If a CBF solution is technically possible and leads to cost savings (under conditions acceptable to the consortium in terms of costs, time frame, etc.), efforts must be made to overcome the administrative/accounting difficulties that have been encountered so far in some cases; a methodology to implement that has been discussed.

The first aspect will be dealt with as business as usual in SA1 Task 2 (procurement). The second aspect is about better understanding what options are in place for connecting a location. This requires extensive pre-procurement work to research and analyse the various options available. This work is also an ongoing process in the procurement activity of GN3 SA1 Task 2. The third aspect, which is essentially about "making CBF work better", was analysed in the fourth workshop. A questionnaire was sent to all NRENs asking them to provide details of connectivity and PoP resources that could be made available to GÉANT. These were summarised and the fourth workshop concluded that the SA1 Task 1 team should:

- Develop evaluation criteria for the resources offered by NRENs, taking into account cost, quality, operations and the actual need for the resources within GÉANT.
- Make proposals to the Exec regarding which NREN resources should be incorporated in GÉANT.

To complement this work, experiences from two major organisations (JA.net and I2) on making use of partner resources were presented. JA.net, in particular, highlighted the technical, operational, and strategic complexities of using partner resources and plan to move away from this model over the course of the next 3-5 years. In their view, the most complex issue in using partner resources is the confusion that arises in the customer/supplier relationship when the users (universities) of the Ja.net network service supply parts of the service that Ja.net offers.

There is an opportunity to further reduce costs by establishing peering interconnections with suitable content and Internet service providers at major Internet Exchanges in Europe. In September 2009, the NREN PC concluded that a trial of connections to IXPs and peerings with major content providers should be undertaken. The impact on the traffic loads across the network will be considered as part of the network planning and minimised where possible.

3.3.4 Network Operations

An overview of the complexities associated with the multi-domain operation of end-to-end (E2E) circuits was discussed in the second workshop. At the same time, the NRENs' experience shows that overall this work is progressing well, especially considering the organisational difficulties. It was stressed that DANTE should play a stronger co-ordinating role between the parties involved for the establishment of E2E circuits.

The main issue to address is the development of efficient processes for the operations of multi-domain services.

With regard to sharing NREN resources, NORDUnet presented their experience with the Nordic Data Grid Facility (NDGF), which, as the name indicates, is focused on GRID operations. NDGF has a central co-ordinating function, with individuals distributed across the Nordic area in different organisations. The experience from GRNET, on the other hand, pointed at re-centralising NOC operations from a previously distributed set-up to achieve a more efficient service.

Prior to the fourth workshop, a questionnaire on network and PoP operations was sent to all NRENs with the purpose of identifying opportunities for increasing NRENs' involvement in GÉANT operations. In general. it was found that the level of support and SLAs that can be expected from NRENs vary greatly, hence it would not be easy to offer a uniform PoP operation across GÉANT. The main conclusions were:

- Where possible, NRENs could host GÉANT PoPs.
- To use NRENs for installation and replacement is difficult due to the mismatch of SLAs.
- For low level operations (e.g. site surveys, supervision of work) there is potential for more involvement of NRENs.

3.3.5 Digital Divide

Four NRENs presented their perspective on the digital divide and how it affects them, as well as what type of actions they would like to see taken up by the consortium. The four NRENS were UoM, IUCC, ULAKBIM and CYNET. There was a general plea to revisit the cost-sharing model taking into account availability of services and placing more emphasis on the geographic issues involved. It was also noted that, in the case of UoM, a cost-effective way of providing better connectivity might be to involve an additional country PoP, complemented by NREN resources, to reach the "standard" PoP. This principle can be exploited in other areas as well. In addition, some NRENs are willing to sacrifice resilience and take on more commercial risk if it allows them access to higher capacities.

The digital divide discussion touched on the more general issue of the clustering of NRENs, and it was concluded that a study of the benefits, drawbacks and cost-sharing implications should be conducted. This study could be conducted by a working group appointed by the Executive or NREN PC.

3.3.6 Global Connectivity

A comprehensive overview of the current situation was given at the third workshop. The presentation highlighted the effectiveness of GÉANT's global connectivity, which is made up of several contributions including those from NRENs. Discussion points covered:

- The use of NREN resources via exchange points and how the GÉANT architecture should facilitate this.
- The need for much stronger co-ordination between GÉANT and NREN initiatives.
- How to sustain connectivity to some regions if co-funding ceases.

4 Capacity Planning Exercise

Periodically DANTE performs surveys in which it solicits input on future backbone network service requirements from all of the GÉANT NRENs. The last of these was a questionnaire distributed to the NRENs at the end of 2008 seeking input on their expectations for GÉANT capacity usage throughout the period of the GN3 project.

4.1 Scope

The scope of the 2008 questionnaire was as follows. Input was sought on:

- IP traffic bandwidth requirements (“R&D” transit to European and international RENs).
- IP traffic bandwidth requirements (“commodity” traffic to/from providers of global upstream IP service, excluding that to/from national peering partners).
- Sub-wavelength point-to-point circuit requirements (e.g. GÉANT Plus), including details of egress (N)REN/PoP where known.
- Full wavelength point-to-point circuit requirements (e.g. GÉANT Lambda), including details of egress (N)REN/PoP where known.
- New services (hitherto unavailable as part of the GÉANT backbone service portfolio, e.g. virtual private LAN service).

In each case, more certainty was envisaged for the first year’s forecast (2009), whereas forecasts for the subsequent years (2010-2012) could be expressed in less certain terms. This means that for the point-to-point circuit services (sub- and full wavelengths), specified far[1] end points were requested for the first year, whereas these were not expected to be provided for the subsequent years. Also, where known, details of applications for each of the forecast “point-to-point” circuit service instances were solicited (e.g. a named project or short description indicating the use to which the circuit was expected to be put).

[1] “Far end” points referring to the point at which the circuit was expected to egress the GÉANT backbone; “near end” points being pre-defined by the PoP associated with the particular NREN providing the forecast.

4.2 Questionnaires

The questionnaires took the form of a Microsoft Excel spreadsheet (a template of which can be found in Appendix A, "Capacity Planning Questionnaire", on page 26). This template was pre-completed with the values for R&D and (where known) commodity IP traffic levels for November 2008 for each NREN before being sent out on a bilateral basis for them to update and/or further complete. Questionnaires were sent to the following NRENs: ACOnet, AMREJ, ARNES, BASNET, BELNET, BREN, CARNET, CESNET, CYnet, DFN, EEnet, FCCN, GARR, GRnet, HEAnet, IUCC, JANET, LITnet, NIIF, NORDUNET, PSNC, REDIRIS, Renam, RENATER, Restena, RoEduNet, SANET, Sigmanet, SURFNET, SWITCH, ULAKBIM and UoM.

4.3 Questionnaire Results

The results of the questionnaire responses received were presented at the second architecture workshop [CapacityAnalysis]. In summary:

- Aggregated IP traffic levels were expected to continue to grow by about 50% per annum (for both R&D and commodity traffic).
- The first GÉANT IP accesses greater than 10 Gbps were expected to be implanted during 2010.
- There was no clear indication that 100 Gbps GÉANT IP access interfaces would be needed during the lifetime of the GN3 project.
- The numbers of sub-wavelength (GÉANT Plus) circuits will increase by about 60 per year (with the aggregate bandwidth of these circuits increasing by about 50% per annum).
- Strong demand was expected for full wavelengths (GÉANT Lambda) at 10 Gbps from about 2010, with some demand for 40 Gbps wavelengths appearing around 2011 (and with aggregate bandwidth again increasing by an average of 50% per annum).

The year-on-year aggregated bandwidth forecasts are shown in the following three graphs:

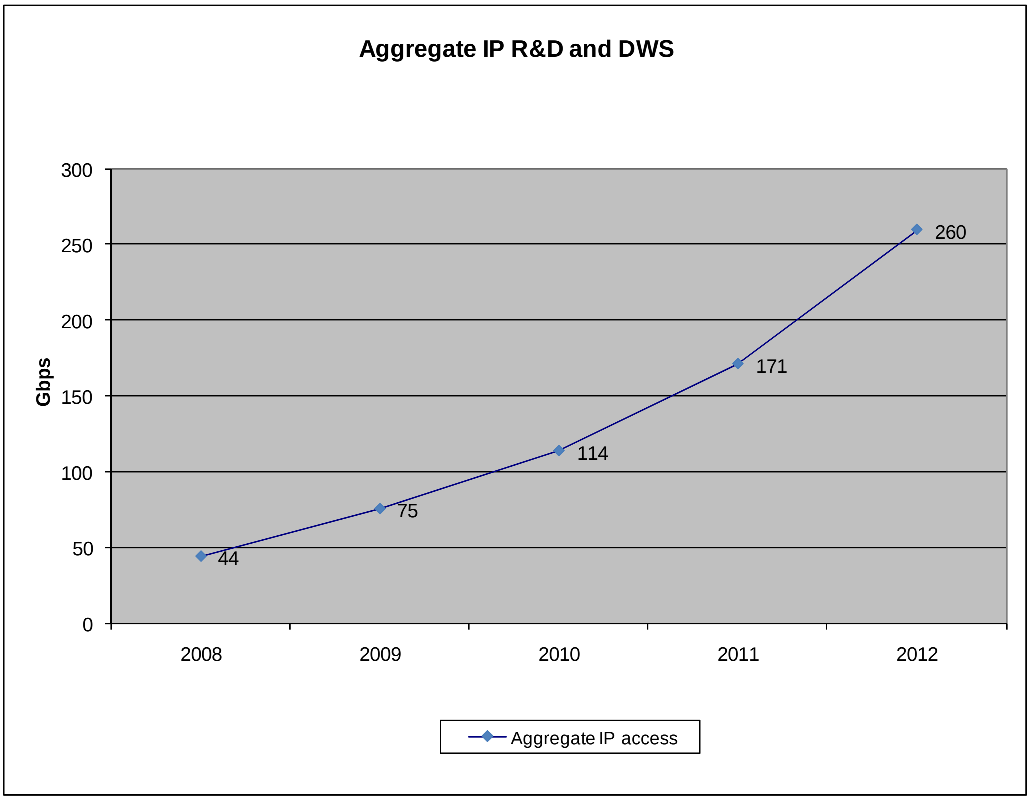

Figure 4.1: Aggregated (R&D and commodity) IP access forecast during GN3

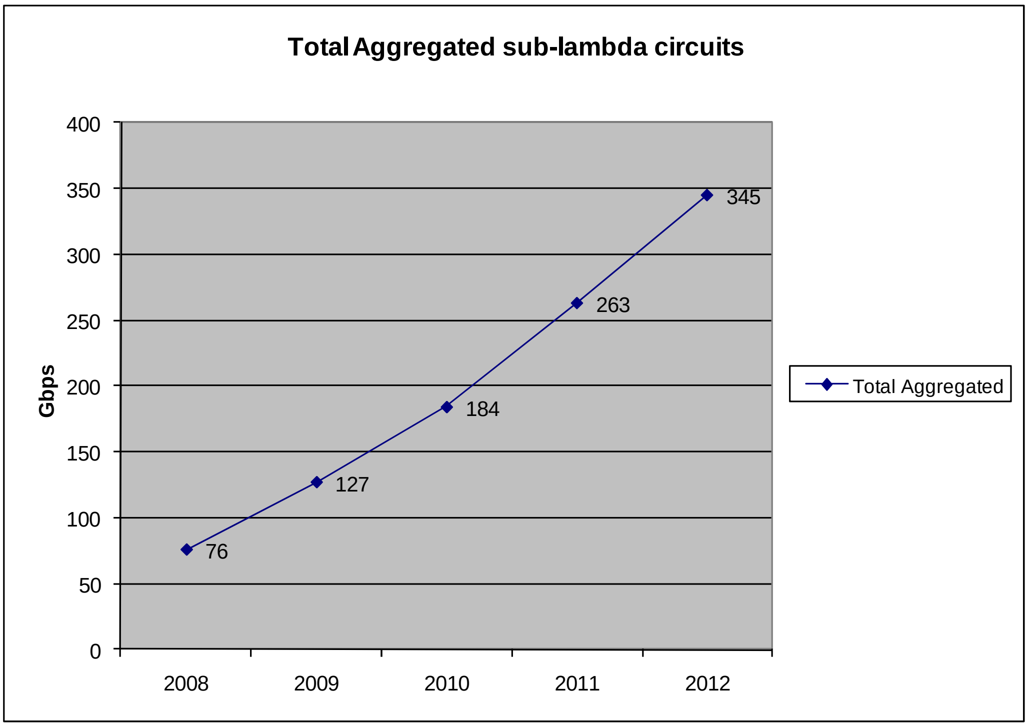

Figure 4.2: Aggregated sub-lambda (GÉANT Plus) circuit bandwidth forecast during GN3

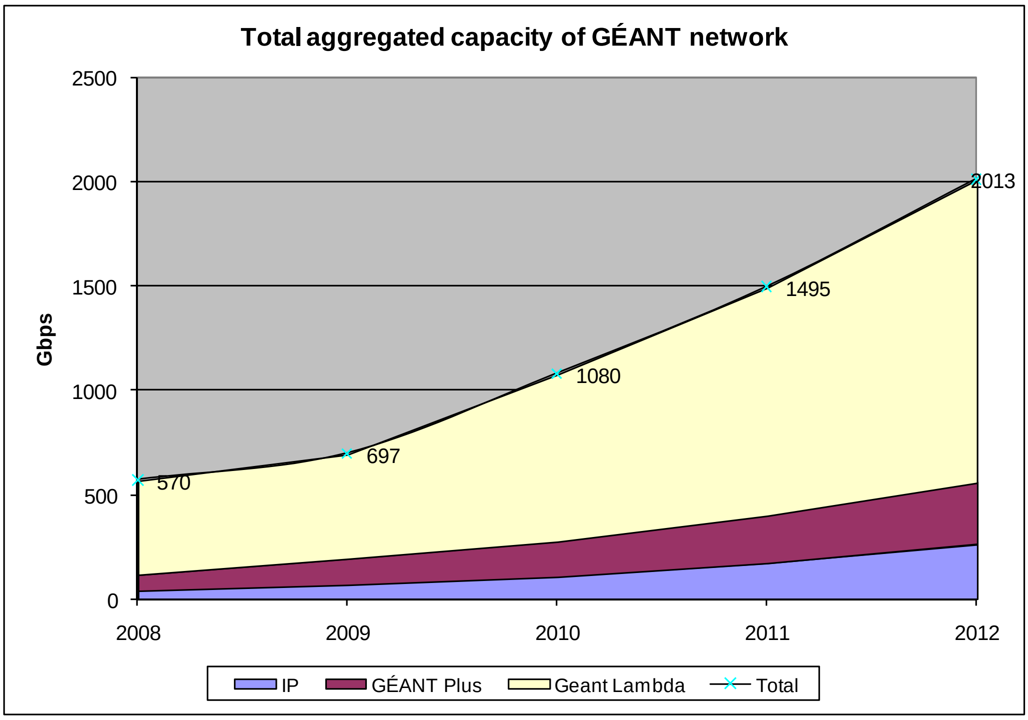

Figure 4.3: Total aggregated bandwidth forecast during GN3 project

Similar growth-level projections were performed at the start of the previous GN2 project. While actual aggregate network capacity was similar to these projections over the same period, the distribution across the network was not as projected. Section 4.5 below looks at the most recent figures and comparisons with actual traffic loads.

4.4 Analysis of Potential Impact on GÉANT Backbone

An analysis was performed to understand the impact of the above results on the GÉANT backbone, specifically with regard to understanding how much transmission capacity would potentially be required to support the forecasted levels of traffic within the timeframe of the GN3 project. This will need to be further complemented by other means such as real traffic flow analysis.

4.4.1 Methodology

In lieu of any firm ideas on how the GÉANT backbone topology may change in any substantive way, the analysis that was done at the beginning of 2009 assumed no change to the topology. Traffic growth profiles were, in part, based on specific traffic additions provided in the questionnaire responses (referring to GÉANT Plus and Lambda services) and, in part, based on organic growth of traffic levels at the per annum rates indicated in the survey results (namely ~50% per annum). More specific details are provided below:

4.4.1.1 *IP backbone*

A simple 50% per annum growth profile was applied to each of the GÉANT backbone IP trunks. It was assumed there would be no redistribution of traffic (e.g. through any substantive changes to the routing setup). Traffic statistics were based on the 95th percentiles of 5-minute samples – in other words levels that are much closer to “peak values” than any longer term average levels. Using the historic network planning design levels, trunk capacity upgrades were triggered when utilisation levels reached about 30% and capacities were incremented in steps of 10 Gbps (equating to the addition of a parallel 10 Gbps wavelength). Some strategic trunks were incremented in capacity over and above levels that would otherwise be indicated by the current traffic distribution and growth profiles. This was done in an attempt to ensure that most failure scenarios did not result in any trunk exceeding a utilisation level of about 80%.

4.4.1.2 *GÉANT Plus platform (for sub-wavelength circuit services)*

For the first two years of the forecast (2009 and 2010), where “specific” circuits were indicated (mainly in the first year of the forecast), the backbone capacity required was accumulated using shortest path routing (in the same manner as circuits would be routed under the normal provisioning procedure). Here the term “specific” means that both the start and end points of the circuits were explicitly provided. Where circuits were forecast with unspecified end points, they were distributed on the backbone by randomly distributing the end points and assuming the number of nodal hops to be 2 or 3 from the starting point (the latter clearly being determined by the NREN providing the forecast for those particular circuits). For years 3 and 4 of the forecast (2011 and 2012), the approach was a bit different since understandably very little information on any circuits in this timeframe was forthcoming. In this case, the same 50% per annum organic growth approach to trunk traffic levels as was applied to the IP backbone was used. This means that the per-trunk traffic levels forecast for 2010 were grown by 50% to yield the 2011 figures and the resulting 2011 figures grown by a further 50% to yield the 2012 figures. Additionally, trunk capacity consumption was based on increments of 155 Mbps, reflecting the current nature of the GÉANT Plus provisioning platform (based on VC-4 centric SDH technology). Hence a gigabit Ethernet circuit consumes seven VC-4s and 64 VC-4s make up a full 10 Gbps wavelength.

4.4.1.3 *GÉANT Lambda platform (for full wavelength circuit services)*

Here the same approach was taken as described above for the sub-wavelength circuits except that a service instance corresponds to a whole wavelength on the relevant trunks (rather than some fraction based on a finite number of 64ths). Where specific service instances have been forecast (with explicit start and end points on the backbone) then these were accumulated according to the usual shortest path routing. Undirected services (those with unspecified end points) were randomly distributed – again with a nodal hop count of 2 or 3.

4.4.2 Results

The results of the impact of the forecast growth in IP traffic are shown in Table 4.1.

Link	end of 2008			end of 2009			end of 2010			end of 2011			end of 2012		
	cap	Gbps	%	cap	Gbps	%	cap	Gbps	%	cap	Gbps	%	cap	Gbps	%
Lon-Ams	10	3.2	32%	20	4.7	23%	30	6.8	23%	40	10.3	26%	50	15.2	30%
Ams-Cop	10	2.6	26%	20	3.8	19%	30	5.6	19%	30	8.4	28%	40	12.3	31%
Cop-Tal	10	1.5	15%	10	2.2	22%	10	3.2	32%	20	4.8	24%	30	7.1	24%
Tal-Rig	10	0.1	1%	10	0.1	1%	10	0.1	1%	10	0.2	2%	10	0.2	2%
Rig-Kau	10	0.1	1%	10	0.1	1%	10	0.2	2%	10	0.2	2%	10	0.4	4%
Kau-Poz	10	1.2	12%	10	1.8	18%	10	2.6	26%	20	3.9	19%	20	5.7	28%
Ams-Fra	10	3.4	34%	20	5.0	25%	30	7.3	24%	40	11.0	27%	50	16.1	32%
Cop-Fra	10	2.0	20%	20	2.9	14%	20	4.2	21%	20	6.3	31%	30	9.3	31%
Lon-Par	10	2.4	24%	20	3.5	18%	20	5.1	26%	30	7.7	26%	40	11.4	28%
Par-Mad	10	0.7	7%	10	1.0	10%	20	1.4	7%	20	2.1	10%	30	3.1	10%
Par-Gen	10	3.3	33%	20	4.8	24%	30	7.0	23%	40	10.7	27%	50	15.7	31%
Mad-Gen	10	3.8	38%	20	5.6	28%	30	8.1	27%	40	12.3	31%	60	18.0	30%
Mad-Mil	10	0.0	0%	10	0.0	0%	20	0.0	0%	20	0.0	0%	30	0.0	0%
Mil-Gen	20	3.1	16%	20	4.5	23%	30	6.6	22%	40	10.0	25%	50	14.7	29%
Fra-Gen	20	5.6	28%	30	8.2	27%	40	12.0	30%	60	18.1	30%	90	26.6	30%
Fra-Poz	10	1.9	19%	10	2.8	28%	20	4.1	20%	30	6.1	20%	30	9.0	30%
Fra-Pra	10	1.5	15%	10	2.2	22%	20	3.2	16%	20	4.8	24%	30	7.1	24%
Poz-Pra	10	0.4	4%	10	0.6	6%	10	0.9	9%	10	1.3	13%	20	1.9	10%
Fra-Vie	10	0.1	1%	10	0.1	1%	20	0.1	1%	20	0.2	1%	20	0.3	2%
Mil-Vie	10	1.7	17%	10	2.5	25%	20	3.6	18%	30	5.5	18%	30	8.1	27%
Vie-Pra	10	0.6	6%	10	0.9	9%	10	1.3	13%	20	1.9	10%	20	2.8	14%
Vie-Bud	10	2.6	26%	20	3.8	19%	20	5.6	28%	30	8.4	28%	40	12.3	31%
Bud-Pra	10	1.3	13%	10	1.9	19%	10	2.8	28%	20	4.2	21%	20	6.2	31%
Vie-Ath	10	2.3	23%	20	3.4	17%	20	4.9	25%	30	7.4	25%	40	10.9	27%
Ath-Sof	10	2.8	28%	20	4.1	21%	20	6.0	30%	30	9.0	30%	50	13.3	27%
Sof-Bud	10	2.9	29%	20	4.3	21%	20	6.2	31%	30	9.4	31%	50	13.8	28%
Sof-Buc	10	0.1	1%	10	0.2	2%	10	0.3	3%	10	0.4	4%	20	0.7	3%
Bud-Buc	10	2.8	28%	10	1.2	12%	10	1.7	17%	10	2.6	26%	20	3.8	19%

Table 4.1: Trunk wavelength capacity (in Gbps) required to support forecast growth in backbone IP traffic

As can be seen above, the busiest backbone trunk with respect to supporting IP traffic (R&D and commodity) is Frankfurt-Geneva with a forecast capacity requirement of 90 Gbps. It is unlikely that such a trunk would ever get implemented as nine 10 Gbps wavelengths – practical possibilities would more likely be two 40 Gbps trunk wavelengths (giving rise to a 33% utilisation level) or a single 100 Gbps trunk wavelength (giving rise to a 27% utilisation).

Additionally, some of the trunks listed in Table 4.1 are not yet part of the GÉANT backbone fibre cloud (e.g. trunks to Athens, Sofia-Budapest, Sofia-Bucharest, etc). Where capacity levels needed are indicated to have to go as high as 50 Gbps (as in the case of Athens-Sofia, for example), this is likely to provide proportionately more justification for the lighting of dark fibre on these routes.

The capacity forecast results arising from the sub-wavelength (GÉANT Plus) services are shown in Table 4.2:

Link	GÉANT Plus				
	2008	2009	2010	2011	2012
Lon-Ams	20	30	30	30	40
Ams-Cop	10	20	20	20	20
Ams-Fra	20	30	40	40	50
Cop-Fra	10	10	10	20	20
Lon-Par	20	20	30	30	30
Par-Mad	10	10	20	20	20
Par-Gen	20	20	30	30	40
Mad-Gen	10	10	20	20	20
Mil-Gen	20	30	40	50	60
Fra-Gen	20	30	30	40	40
Fra-Poz	20	20	20	20	30
Fra-Pra	20	30	40	40	50
Poz-Pra	10	10	10	10	10
Mil-Vie	10	20	30	30	40
Vie-Ath	0	10	10	10	10
Bud-Buc	n/a	10	20	20	20
Bra-Vie	20	30	40	50	50
Bra-Pra	20	30	30	40	40
Bra-Bud	10	20	30	30	40
Bud-Zag	10	10	10	10	10
Zag-Lju	10	10	10	10	10
Lju-Vie	10	20	20	20	20
Mil-Ath	10	10	10	20	20
Dub-Lon	20	20	20	30	30
Lon-Bru	10	10	10	10	10
Bru-Ams	10	10	10	10	10
Mad-Lis	<10	10	10	10	20
Ist-Buc	n/a	n/a	10	10	10

Table 4.2: Trunk wavelength capacity (in Gbps) required to support forecast growth in backbone sub-wavelength (GÉANT Plus) traffic

And finally the same arising from the full wavelength (GÉANT Lambda) services are shown in Table 4.3.

Link	GÉANT lambdas				
	2008	2009	2010	2011	2012
Lon-Ams	60	60	100	130	130
Ams-Cop	10	10	10	10	10
Ams-Fra	110	140	220	270	280
Cop-Fra	20	20	50	60	60
Lon-Par	60	60	90	90	90
Par-Gen	60	60	100	120	120
Mad-Gen	30	40	80	90	90
Mil-Gen	20	30	80	120	130
Fra-Gen	130	150	200	260	280
Fra-Pra	40	50	110	150	160
Mil-Vie			30	80	80
Bud-Buc				30	30
Bra-Vie			40	80	80
Bra-Pra			50	80	80
Bra-Bud			10	80	80
Bud-Zag				20	20
Zag-Lju				10	10
Lju-Vie			30	30	30
Lon-Bru			20	20	20
Bru-Ams			30	60	60
Mad-Lis		10	30	30	30
Ist-Buc				20	20

Table 4.3: Trunk wavelength capacity (in Gbps) required to support forecast growth in full wavelength (GÉANT Lambda) services

Again, Frankfurt-Geneva looks like it will continue to be the “busiest” transmission trunk along with (in this case) Amsterdam-Frankfurt.

Bringing everything together and “translating” some of the IP and GÉANT Plus trunks into the real underlying transmission trunks from which they are comprised, the results can be seen in Table 4.4. An example of this translation is as follows. The IP backbone trunk Vienna-Prague really consists of two transmission trunks: Vienna-Bratislava and Bratislava-Prague. Likewise, the notional Ljubljana-Vienna GÉANT Plus backbone trunk actually translates to the two transmission trunks Ljubljana-Finkenstein and Finkenstein-Vienna. (Finkenstein is the site of a three-way transmission regenerator node, near Klagenfurt in Austria, on the long Milan-Vienna link where the dark fibre coming up from Ljubljana joins up with the Milan-Vienna link.

Link	IP trunks					GÉANT Plus					GÉANT lambdas					Totals per WDM link				
	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
Lon-Ams	10	20	30	40	50	20	30	30	30	40	60	60	100	100	130	90	110	160	170	220
Ams-Cop	10	20	30	30	40	10	20	20	20	20	10	10	10	10	10	30	50	60	60	70
Cop-Tal	10	10	10	20	30	n/a	n/a	n/a	n/a	n/a						10	10	10	20	30
Tal-Rig	10	10	10	10	10	n/a	n/a	n/a	n/a	n/a						10	10	10	10	10
Rig-Kau	10	10	10	10	10	n/a	n/a	n/a	n/a	n/a						10	10	10	10	10
Kau-Poz	10	10	10	20	20	n/a	n/a	n/a	n/a	n/a						10	10	10	20	20
Ams-Fra	10	20	30	40	50	20	30	40	40	50	110	140	220	240	280	140	190	290	320	380
Cop-Fra	10	20	20	20	30	10	10	10	20	20	20	20	50	50	60	40	50	80	90	110
Lon-Par	10	20	20	30	40	20	20	30	30	30	60	60	90	90	90	90	100	140	150	160
Par-Mad	10	10	20	20	30	10	10	20	20	20						20	20	40	40	50
Par-Gen	10	20	30	40	50	20	20	30	30	40	60	60	100	100	120	90	100	160	170	210
Mad-Gen	10	20	30	40	60	10	10	20	20	20	30	40	80	80	90	50	70	130	140	170
Mad-Mil	10	10	20	20	30	n/a	n/a	n/a	n/a	n/a						10	10	20	20	30
Mil-Gen	20	20	30	40	50	20	30	40	50	60	20	30	80	110	130	60	80	150	200	240
Fra-Gen	20	30	40	60	90	20	30	30	40	40	130	150	200	210	280	170	210	270	310	410
Fra-Poz	10	10	20	30	30	20	20	20	20	30						30	30	40	50	60
Fra-Pra	10	10	20	20	30	20	30	40	40	50	40	50	110	150	160	70	90	170	210	240
Poz-Pra	10	10	10	10	20	10	10	10	10	10						20	20	20	20	30
Fra-Vie	10	10	20	20	20	n/a	n/a	n/a	n/a	n/a						10	10	20	20	20
Mil-Vie	10	10	20	30	30	10	20	30	30	40			30	80	80					
Vie-Pra	10	10	10	20	20	n/a	n/a	n/a	n/a	n/a						10	10	10	20	20
Vie-Bud	10	20	20	30	40	n/a	n/a	n/a	n/a	n/a						10	20	20	30	40
Bud-Pra	10	10	10	20	20	n/a	n/a	n/a	n/a	n/a										
Vie-Ath	10	20	20	30	40	0	10	10	10	10						10	30	30	40	50
Ath-Sof	10	20	20	30	50	n/a	n/a	n/a	n/a	n/a						10	20	20	30	50
Sof-Bud	10	20	20	30	50	n/a	n/a	n/a	n/a	n/a						10	20	20	30	50
Sof-Buc	10	10	10	10	20	n/a	n/a	n/a	n/a	n/a						10	10	10	10	20
Bud-Buc	10	10	10	10	20	n/a	10	20	20	20				30	30	10	20	30	60	70
Bra-Vie	20	30	30	50	60	20	30	40	50	50			40	80	80	40	60	110	180	190
Bra-Pra	20	20	20	40	40	20	30	30	40	40			50	80	80	40	50	100	160	160
Bra-Bud	20	30	30	50	60	10	20	30	30	40			10	80	80	30	50	70	160	180
Bud-Zag	30	50	50	70	80	10	10	10	10	10				20	20	40	60	60	100	110
Zag-Lju	30	50	50	70	80	10	10	10	10	10				10	10	40	60	60	90	100
Lju-Vie	10	20	20	30	30	10	20	20	20	20			30	30	30					
Lju-Bud	10	20	20	30	30															
Zag-Vie	10	10	10	10	10															
Zag-Bud[2]	10	10	10	10	10															
Lju-Fin	30	50	50	70	80	10	20	20	20	20	0	0	30	30	30	40	70	100	120	130
Fin-Vie	40	60	70	100	110	20	40	50	50	60	0	0	60	110	110	60	100	180	260	280
Mil-Fin	10	10	20	30	30	10	20	30	30	40	0	0	30	80	80	20	30	80	140	150
Mil-Ath						10	10	10	20	20						10	10	10	20	20
Dub-Lon	20	20	20	20	20	20	20	20	30	30						40	40	40	50	50
Lon-Bru	10	10	10	10	20	10	10	10	10	10			20	20	20	20	20	40	40	50
Bru-Ams	10	10	10	10	20	10	10	10	10	10			30	50	60	20	20	50	70	90
Par-Lux	10	10	10	10	10	<10										10	10	10	10	10
Lux-Fra	10	10	10	10	10	<10										10	10	10	10	10
Mad-Lis	10	10	20	20	20	<10	10	10	10	20		10	30	30	30	10	30	60	60	70
Ist-Buc	<10	<10	<10	<10	<10	n/a	n/a	10	10	10				20	20	0	0	10	30	30

Table 4.4: Total per trunk capacity requirement forecast (in Gbps)

A key point to note about Table 4.4 is that two of the backbone transmission trunk links get close to or exceed forty 10 Gbps wavelengths. This is the limit of the transmission platform as it is currently engineered and is a clear indication that, if retained,the current platform will need to be upgraded either more than forty 10 Gbps wavelengths per fibre pair or, more preferably, 40 Gbps and/or 100 Gbps channels.

4.5 2009 Check on Original Capacity Requirement Forecast

The fact that a year has passed since the forecast described above was originally made allows us to check on whether the original backbone transmission capacity forecast has hitherto been borne out by real growth figures. The short answer is that over the last 12 months it has only been partially borne out for the IP traffic and considerably less so for the sub- and full wavelength services. A revision of the IP component of the transmission capacity forecast (prepared at the end of 2009) is shown in Table 4.5. This shows that growth was less than originally forecast – e.g. London-Amsterdam was originally estimated to rise from 3.2 Gbps to 4.7 Gbps by the end of 2009 whereas in reality a growth to a more modest 3.5 Gbps has been seen. That having been said, it is still the case that many of the 1×10 Gbps to 2×10 Gbps IP trunk upgrades that were originally predicted to be required at some point during 2009 are indeed now actually required and will need to be implemented during the first half of 2010. Most of these are on the so-called “Western Ring” of the transmission network and are shown in Table 4.5 as lines for which the percentage utilisation in 2009 is coloured blue. The 2×10 Gbps to 3×10 Gbps upgrade that was originally forecast for one of the sections on the Western Ring (namely Frankfurt-Geneva) is also still required but, at the time of writing, it is likely that this will be implemented as a single 40 Gbps wavelength (that is anyway being trialled on that particular link). Some of the IP trunk upgrades that were envisaged during 2009 appear to not now be required before the end of 2010. 2009 growth figures for backbone trunk capacity to support GÉANT Plus and GÉANT Lambda services are considerably down on what was originally forecast at the end of 2008. Despite this, significant growth in demand for all the GÉANT backbone services is still expected to take place during the GN3 project. As new rounds of projects that need substantive network connectivity service are approved for funding and start to come on line then it is expected that the capacity growth profile in time just exhibits delayed yet sizeable upward steps rather than the continuous steady growth profile that was used in this simple modeling. This was certainly seen to be the case throughout the GN2 project.

As a result further work is needed to evaluate whether the last 12 months indicate a future trend or not. Overall projections need to be refined, particularly taking into account historical data while also projecting the future needs of new high-data demands that could materialise from the ESFRI projects where data is observed in some scientific fields to double every year.

4.6 Conclusions on Capacity Planning

The main conclusions that were drawn from this work are as follows:

- The current GÉANT DWDM transmission platform will most likely need to undergo upgrade or replacement before the end of the GN3 project.

- 40 Gbps transmission capability on the GÉANT backbone is needed now on some specific routes. Further work is needed to evaluate whether this capability will be required across the network before the availability of 100 Gbps transmission capability is commercially realistic.

- Based on the initial demand forecasts across the current topology and architecture (which need further evaluation), 100 Gbps transmission capability on the GÉANT backbone would be predicted to be needed from the end of 2011/start of 2012.

Link	Actual 95th percentile usage						Forecast 95th percentile usage								
	end of 2008			end of 2009			end of 2010			end of 2011			end of 2012		
	cap	Gbps	%	cap	Gbps	%	cap	Gbps	%	cap	Gbps	%	cap	Gbps	%
Lon-Ams	10	3.2	32%	10	3.5	35%	20	5.3	26%	30	7.9	26%	40	11.8	30%
Ams-Cop	10	2.6	26%	10	1.5	15%	10	2.3	23%	20	3.4	17%	20	5.1	25%
Cop-Tal	10	1.5	15%	10	1.2	12%	10	1.8	18%	10	2.7	27%	20	4.1	20%
Tal-Rig	10	0.1	1%	10	0.5	5%	10	0.8	8%	10	1.1	11%	10	1.7	17%
Rig-Kau	10	0.1	1%	10	0.5	5%	10	0.8	8%	10	1.1	11%	10	1.7	17%
Kau-Poz	10	1.2	12%	10	0.7	7%	10	1.1	11%	10	1.6	16%	10	2.4	24%
Ams-Fra	10	3.4	34%	10	3.6	36%	20	5.4	27%	30	8.1	27%	40	12.2	30%
Cop-Fra	10	2.0	20%	10	2.5	25%	20	3.8	19%	20	5.6	28%	30	8.4	28%
Lon-Par	10	2.4	24%	10	3.4	34%	20	5.1	26%	30	7.7	26%	40	11.5	29%
Par-Mad	10	0.7	7%	10	1.0	10%	10	1.5	15%	10	2.3	23%	20	3.4	17%
Par-Gen	10	3.3	33%	10	2.5	25%	20	3.8	19%	20	5.6	28%	30	8.4	28%
Mad-Gen	10	3.8	38%	10	4.0	40%	20	6.0	30%	30	9.0	30%	50	13.5	27%
Mad-Mil	10	0.0	0%	10	0.0	0%	10	0.0	0%	20	0.0	0%	20	0.0	0%
Mil-Gen	20	3.1	16%	20	4.5	23%	30	6.8	23%	40	10.1	25%	50	15.2	30%
Fra-Gen	20	5.6	28%	20	6.5	33%	40	9.8	24%	50	14.6	29%	80	21.9	27%
Fra-Poz	10	1.9	19%	10	1.5	15%	10	2.3	23%	20	3.4	17%	20	5.1	25%
Fra-Pra	10	1.5	15%	10	2.5	25%	20	3.8	19%	20	5.6	28%	30	8.4	28%
Poz-Pra	10	0.4	4%	10	0.2	2%	10	0.3	3%	10	0.5	5%	10	0.7	7%
Fra-Vie	10	0.1	1%	10	0.1	1%	20	0.2	1%	20	0.2	1%	20	0.3	2%
Mil-Vie	10	1.7	17%	10	1.0	10%	10	1.5	15%	10	2.3	23%	20	3.4	17%
Vie-Pra	10	0.6	6%	10	2.0	20%	10	3.0	30%	20	4.5	23%	20	6.8	34%
Vie-Bud	10	2.6	26%	10	3.0	30%	20	4.5	23%	30	6.8	23%	40	10.1	25%
Bud-Pra	10	1.3	13%	10	1.2	12%	10	1.8	18%	10	2.7	27%	20	4.1	20%
Vie-Ath	10	2.3	23%	10	3.7	37%	20	5.6	28%	30	8.3	28%	50	12.5	25%
Ath-Sof	10	2.8	28%	10	0.5	5%	10	0.8	8%	10	1.1	11%	10	1.7	17%
Sof-Bud	10	2.9	29%	10	0.6	6%	10	0.9	9%	10	1.4	14%	10	2.0	20%
Sof-Buc	10	0.1	1%	10	0.8	8%	10	1.2	12%	10	1.8	18%	10	2.7	27%
Bud-Buc	10	2.8	28%	10	0.7	7%	10	1.1	11%	10	1.6	16%	10	2.4	24%

Table 4.5: Trunk wavelength capacity (in Gbps) required to support forecast growth in backbone IP traffic (revisited 2009)

5 Status Summary and Further Work

5.1 Introduction

At the time of writing (March 2010), some significant pieces of analysis have been completed (as described in this report) but quite a few more are needed to be completed before sufficient information will be available to bring together a broadly accepted architectural goal upon which the rest of the GN3 project (and beyond) can be based. These are outlined in this section and represent a statement of the work plan of SA1 Task 1 during the next 6 months.

The general focus of this work is to:

- Understand fully the short-term modifications that could be made to the current backbone IP routing architecture (specifically with a view to supporting IP peering traffic).
- Understand fully the different options for upgrading the transport capabilities of the GÉANT backbone to support 40 and 100Gbps transmission and wavelength switching.
- Decide on a strategy for the enhancement of the current sub-wavelength switching capability whilst at the same time migrating away from the current NG-SDH technology. Alternative techniques to the current NG-SDH technology should be sought, such as Carrier Ethernet EoMPLS and OTN.
- Understand the options for converging some or all of the three network layers that exist today (IP routing, sub-wavelength switching and optical transmission). In the shorter term, two of these could reasonably be expected to be converged. In the longer term, it might be possible to converge all three.
- Understand the topological changes that can reasonably be made to the backbone and what part the utilisation of NREN infrastructure resources can play in this.
- Identify new locations that might improve overall GÉANT service resilience (through multiple diverse accesses for as many NRENs as possible) and general accessibility and study the feasibility of providing access (to the transmission layer) at these locations. These locations will include Optical Exchange Points and other exchange sites.

This represents the remainder of what can be thought of as an “architecture phase” with regard to the GÉANT backbone. This will then be followed by procurement, rollout and operating phases lasting up until the end of the GN3 project and beyond.

Appendix A Capacity Planning Questionnaire

This appendix contains screenshots of a blank template for the capacity questionnaire that was distributed to NRENs at the end of 2008. The actual Excel file sent to the individual NRENs contained real data (e.g. the values for R&D and, where known, commodity IP traffic levels for November 2008) and logic to pre-populate some of the cells for the NREN to update and/or further complete.

	GN3-NREN bandwidth questionnaire 2009-2012					
	NREN NAME	<select NREN>				
	Current GEANT IP peak traffic observed (Gbps)	X	Gbps			
	Current GÉANT Plus usage (nr of circuits):	Y	nr of circuits			
	Current GÉANT Lambda usage (nr of circuits):	Z	nr of lambdas			
	Introduction					
	The purpose of this questionnaire is to identify the bandwidth requirements of the NRENs participating in the GN3 project. The information sought by this survey is: IP traffic, sub-wavelength point-to-point and lambda circuit bandwidth requirements over the lifetime of the GN3 project. It also tries to identify bandwidth requirements for potential future services.					
	The questionnaire is looking at the short term planned requirements in 2009 and over the estimated long term requirements 2010-2012 period for each participating GN3 - NREN.					
	Please insert your values in the yellow cells					
	IP access requirements					
	The next two questions would like to assess your international IP traffic bandwidth requirements for connectivity towards research and education networks (RENs) in Europe and across the world. By international IP traffic we understand any traffic which has its source or destination in the NREN and excludes national traffic.					
Q1	Thinking about the IP traffic currently exchanged between your NREN and European and international RENs what is your planned IP traffic usage increase, in percentage, compared to the previous year over the next four years ? (for 2010, 2011, 2012 your best estimates will be fine)					
		Current used peak traffic Nov 2008(Gbps)	Percentage increase			
			2009 (planned)	2010 (estimated)	2011 (estimated)	2012 (estimated)
	Percentage (%) increase		0%	0%	0%	0%
	Peak R&E bandwidth usage (Gbps)	0	0	0	0	0

Q2	Thinking about the IP traffic exchanged between your NREN and global IP access (excluding local national peerings) what is your planned IP traffic usage increase, in percentage, compared to the previous year over the next four years ? (for 2010, 2011, 2012 your best estimates will be fine)					
			Percentage increase			
		Current traffic Nov 2008(Gbps)	2009 (planned %)	2010 (estimated %)	2011 (estimated %)	2012 (estimated %)
	Percentage (%) increase		0%	0%	0%	0%
	Peak global IP bandwidth usage (Gbps) --> Please insert value in Gbps if current value different -->	0	0	0	0	0

Sub-wavelength circuit requirements

In the next questions we would like to assess your sub-wavelength circuit bandwidth requirements towards European and other International partners. By sub-wavelength circuits we understand any point-to-point Ethernet or SDH circuit which doesn't fully utilise a 10G, 40G or 100G wavelength, can be established and decommissioned at short notice (days) and it has a lifetime between a few hours to 4 years.

		2009 - planned			
		Id	Capacity of the circuit(Gbps)	End point NREN	Application
Q3	For each new sub-wavelength p2p circuit that you plan for 2009 please specify the bandwidth required in Gbps, the end-point NREN if known and the application if known.	1			
		2			
		3			
		4			
		....			

		2010 (best estimate)			
		Id	Capacity of the circuit(Gbps)	End point NREN (if known)	Application (if known)
		1			
		2			
		3			
		4			
		....			

		2011 (best estimate)			
		Id	Capacity of the circuit(Gbps)	End point NREN (if known)	Application (if known)
Q4	For each new sub-wavelength p2p circuit that you envisage for 2010, 2011 and 2012 please specify the bandwidth required in Gbps. Your best estimates will be fine and if a breakdown is not available, please estimate the total capacity envisaged for sub-wavelength p2p circuits.	1			
		2			
		3			
		4			
		....			
		2012 (best estimate)			
		Id	Capacity of the circuit(Gbps)	End point NREN (if known)	Application (if known)
		1			
		2			
		3			
		4			
		....			

Lambda circuits requirements

In the next questions we would like to assess your lambda circuit bandwidth requirements towards European and other International partners. By lambda circuits we mean any point-to-point circuit which fully utilise a full 10G or 40G wavelength and it has a lifetime of anything between 1 years to 4 years.

		2009 - planned			
		Id	Capacity of the circuit(Gbps)	End point NREN	Application
Q5	For each new lambda p2p circuit that you plan for 2009 please specify the bandwidth required in Gbps, the end-point NREN if known and the application if known.	1			
		2			
		3			
		4			
		....			

		2010 - best estimate			
		Id	Capacity of the circuit(Gbps)	End point NREN (if known)	Application (if known)
		1			
		2			
		3			
		4			

Q6	For each new lambda p2p circuit that you envisage for 2010, 2011 and 2012 please specify the bandwidth required in Gbps, the end-point NREN if known and the project if known. Your best estimates will be fine and if a breakdown is not available please estimate the total capacity envisaged for lambda p2p circuits	... ..				
		2011 - best estimate				
		Id	Capacity of the circuit(Gbps)	End point NREN (if known)	Application (if known)	
		1				
		2				
		3				
		4				
		... ..				
		2012 - best estimate				
		Id	Capacity of the circuit(Gbps)	End point NREN (if known)	Application (if known)	
		1				
		2				
		3				
		4				
		... ..				
	Future services bandwidth requirements					
	In the next question we would like to assess your other traffic requirements not catered currently at European or international level, traffic which may be resulted from new services.					
Q7	Thinking about new services planned to be developed by your NREN over the next 4 years (i.e. between 2009-2012), please provide your best estimate of the capacity in Gbps envisaged, type of service, and year of introduction, in so far they could affect your international bandwidth requirements. By "Type of Service" we mean for example: point-to-multipoint and multipoint-to-multipoint services delivered via NG-Ethernet, Virtual Private LAN Services (VPLS), or any other services planned to be developed by your NREN.	Id	Capacity of the envisaged services (Gbps)	Type of service (if known)	Year of introduction (if known)	Comments
		1				
		2				
		3				
		4				
		5				
		6				
		... ..				
Q8	If there are any other comments or suggestions you would like to make about your future bandwidth requiremenst, please insert in the next cell.					

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Glossary

CBF	Cross-Border Fibre
CD	Competitive Dialogue
CIP	Commodity IP
DWDM	Dense Wavelength Division Multiplexing
DWS	DANTE World Service
E2E	End to End
EoMPLS	Ethernet over Multi-Protocol Label Switching
GE	Gigabit Ethernet
GOLE	Global Optical Lightpath Exchange
IX	Internet Exchange
IXP	Internet Exchange Point
IP	Internet Protocol
ISP	Internet Service Provider
LSP	Label Switched Path
MPLS	Multi-Protocol Label Switching
NG-SDH	Next Generation Synchronous Digital Hierarchy
NOC	Network Operations Centre
NREN	National Research and Education Network
OJEU	Official Journal of the European Union
OTN	Optical Transport Network
p2p	point to point
PIN	Prior Information Notice
PoP	Point of Presence
RFI	Request for Information
SLA	Service Level Agreement
TCO	Total Cost of Ownership
WI	Work Item
WSS	Wavelength Selective Switching