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Deliverable DS1.1.3,3: Annual Report

SA1 Network Build and Operations: Task 1 Network Planning and Procurement Preparation

Deliverable DS1.1.3,3

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Abstract

Third annual report for SA1 Network Build and Operations, Task 1 Network Planning and Procurement Preparation.

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Executive Summary

Task 1 of GN3 Service Activity 1 is the network planning and procurement preparation work concerned with enhancing the GÉANT backbone, the cost-shared part of the Europe-wide research and education network infrastructure operated by DANTE. It has been the objective of this Task to conduct a thorough review of the existing GÉANT network architecture, to assess whether factors such as the costs and technical capabilities of connectivity and of switching and routing hardware, or shared fibre, might challenge its assumptions about cost-effective structures. This document is the Task's third annual report, covering progress during Project Year 3 in the following areas: regional connectivity strategy studies, GÉANT IP design, additional access points (AAPs) and near-term capacity planning. It concludes with an assessment of the achievements and status of the Task as at the end of Year 3, and a summary of the work to be conducted in Year 4.

The aims of the regional connectivity strategy studies, which are co-ordinated and largely conducted by groups of NREN experts from the relevant regions, are to increase resilience; decrease cost; reduce the risk of network failure; and increase possibilities for NREN AAPs. The SA1 team reviews the recommendations provided by the regional study groups for issues such as compatibility across the whole network, then recommends a final solution to the SA1 Supervisory Committee for forwarding to the Executive Committee. By the end of Y3 Q1 the studies had been largely completed and a consolidated regional studies report produced. In Q2, recommendations regarding the regions that needed the most urgent attention were submitted for approval. This led to a number of conclusions affecting the near-term connectivity procurement activity. The studies have also provided input to the major GÉANT transmission and switching equipment procurement.

SA1 Task 1 carried out an overall redesign of the GÉANT IP platform architecture and how it might change in light of the changes that will be made to the GÉANT switching platform as a result of the transmission and switching equipment procurement. The work has resulted in an architecture that in turn translated into explicit hardware capacity requirements for the transmission and switching equipment procurement. The resulting plan will be refined in the light of the outcome of the Lot 2 procurement and ongoing discussions with the selected supplier.

A third area of activity in Year 3 has been to consider in detail options for realising additional network access points (AAPs) in the candidate locations identified in the Year 2 deliverable DS1.1.1,2 "Final GÉANT Architecture". The most notable of these locations was Hamburg. This work is ongoing. Further AAP options (e.g. Marseilles) have been discussed in the regional studies.

As part of Operations' regular near-term capacity planning activity the Task reviewed the peer network traffic matrix. As a result, backbone trunk upgrades have been performed to accommodate traffic growth, part of which is attributed to the addition to the core traffic matrix of the peering traffic and its ongoing growth.

SA1 Task 1 was originally planned to finish at the end of Y2, with much of the resource allocated to architecture development then moving to SA1 Task 2 procurement-related activity. To this end, the Year 3 plan for Task 1 foresaw the use of a limited amount of manpower to undertake activities outstanding from Year 2 described above. Manpower will be slightly increased in Year 4 to continue these activities and begin others. The regional studies report will be revised as and when more information regarding certain regions becomes available, and further studies will be undertaken. The redesigned GÉANT IP layer architecture will be reviewed and the migration plan resulting from it refined in the light of the outcome of the Lot 2 procurement and ongoing discussions with the selected supplier. Detailed consideration of additional network access points and near-term capacity planning are ongoing. In addition, the Task will develop an overall GN3 testbed strategy and plan, and analyse the possibilities of brokering commercial cloud services for the NREN community.

1 Introduction

Task 1 of GN3 Service Activity 1 is the network planning and procurement preparation work concerned with enhancing the GÉANT backbone – that is, the cost-shared part of the Europe-wide research and education (R&E) network infrastructure operated by DANTE.

When the GN3 project was conceived and the plan was being developed, it was recognised that the preceding GN2 project had already implemented a hybrid network infrastructure on which GN3 could build. Nevertheless, this did not necessarily imply that the architecture and design of the network would remain unchanged during GN3. It was thought that considerations relating to the costs and technical capabilities of connectivity and of switching and routing hardware might challenge existing assumptions about cost-effective structures. There was also (and still is) the possibility of shared fibre acquisition and/or shared fibre use between National Research and Education Networks (NRENs) and GÉANT as a means to realise potential cost savings. It was even thought that joint-lighting of routes between the project and connectivity suppliers might be possible. It has therefore been the objective of this Task to conduct a thorough review of the GÉANT network architecture and analyse these factors.

Task 1 was originally intended to be wound down around Y3 Q1, with Task participants becoming more involved in procurement-related activities in Task 2, which were increasing in intensity. To this end, the Year 3 plan for Task 1 foresaw the use of a limited amount of manpower (about 20 MM) to tie up a few loose ends left over from Year 2 as described in Section 7.1.2.3 of the deliverable DN1.1.2,2 “Annual Project Management Report – Year 2” [DN1.1.2,2]. The most notable of these loose ends were the completion of the regional connectivity strategy studies and a piece of work aimed at re-architecting the GÉANT IP layer. Two further areas of work were the additional access points (AAP) study and near-term capacity planning.

The first and second annual reports on the progress of this work during Project Years 1 and 2 were provided in deliverables DS1.1.3,1 and DS1.1.3,2 [DS1.1.3,1, DS1.1.3,2]. This document is the third annual report, on progress during Year 3.

The document covers the following topics:

- Summary of work conducted during Year 3, covering regional connectivity strategy studies, GÉANT IP design, additional access points (AAP) study and near-term capacity planning (Section 2).
- An assessment of the achievements and status of the Task as at the end of Year 3 and a summary of the work to be conducted in Year 4 (Section 3).

Summaries of the work carried out during Year 1 and Year 2 are provided in Appendix A and Appendix B respectively. An extended summary of the "Final GÉANT Architecture" deliverable, a key output from Year 2, is provided in Appendix C.

2 Summary of Work Conducted During Project Year 3

2.1 Introduction

By the beginning of Year 3, SA1 Task 1's work plan consisted of four sets of sub-tasks focusing on:

- Regional connectivity strategy studies.
- GÉANT IP design.
- Additional access points (AAP) study.
- Near-term capacity planning.

This section summarises the Year 3 work in each of these areas.

2.2 Regional Connectivity Strategy Studies

The aims of the regional connectivity strategy studies are to:

- Increase resilience.
- Decrease cost.
- Reduce the risk of network failure.
- Increase possibilities for NREN alternative access points (AAPs).

Increasing the resilience of the GÉANT network (which includes resilience of NRENs' access) is of great importance. Greater resilience can be achieved by improvements in a combination of fibre topology, optical technologies and upper layers.

The studies are conducted largely by groups of experts from the relevant local NRENs, each with one co-ordinating partner. In this set of studies, potential solutions for connectivity are identified by the regional teams and, if applicable, compared with NREN cross-border fibre (CBF) offerings (in accordance with the capacity acquisition process). If a CBF solution is not offered, or if the estimated availability date is more than a year

away, or if it is not recommended for a given location, then connectivity may be procured following a public tender for leased capacity and/or dark fibre.

The SA1 team considers the recommendations provided by the regional study groups and reviews them for issues such as compatibility across the whole network. This may lead to further iterations before a final solution is recommended to the Executive Committee via the SA1 Supervisory Committee.

The way in which these regional studies have been divided up is shown in Table 2.1 below.

Region	Current GÉANT PoPs Affected	Co-ordinating Partner
Western Ring	UK, BE, NL, DE, CH, FR	DANTE
Paris/Brussels-Lux-Frankfurt	FR, BE, LU, DE	RESTENA
Lisbon & Madrid (including links out of Madrid to Paris, Geneva & Milan)	PT, ES, FR, CH, IT, UK	RedIRIS
Milan-Marseille	IT, Marseille (ILA on CH-ES)	GARR
Third route out of Geneva	CH, IT, Lyon & Marseille (ILAs on CH-ES)	SWITCH
Baltic Ring and Copenhagen	DK, EE, LV, LT, PL, Hamburg (ILA/splice on NL-DK, DE-DK)	NORDUnet
Dublin	UK, IE	HEAnet
Eastern Ring (excluding DE-CH)	DE, CZ, SK, AT, IT, CH, Finkenstein	CESNET
Poland	DE, CZ, PL, LT	PSNC
Budapest-Croatia-Slovenia-Finkenstein	SK, HU, HR, SI, Finkenstein	HUNGARNET
Moscow	DK, DE, RU	NORDUnet
SEE (including Romania, Moldova, Bulgaria, Serbia, Montenegro, FYROM, Greece & Cyprus)	HU, RO, BG, GR, CY, AT, IT	GRNET
Turkey	BG, RO	DANTE
Malta & Israel	IT, DE, UK	IUCC and UoM
Hamburg AAP	Hamburg (ILA & splice)	DFN
Marseille AAP	Marseille (ILA)	RENATER

Table 2.1: Structure of regional connectivity strategy studies

By the end of Y3 Q1 the studies had been largely completed and a consolidated regional studies report produced [RegStudies] consisting of summaries of the studies, including their status and recommendations, and procurement decisions. This is a living document and as such was subject to revision throughout the rest of the year as and when more information regarding certain regions became available; this will continue to be the case until the end of the project. In addition, further studies will be undertaken during Year 4.

The report consists of the following sections:

- Executive Summary.
- Background.
- Summary of latest status – tables describing the twelve-month strategy for reprocurement of leased wavelengths and procurement of new dark fibre as recommended by the regional study teams.
- Explanations of recommendations for:
  - Leased wavelength re-procurement.
  - High-priority dark fibre / cross-border fibre procurement.
  - Lower priority CBF procurement.

The report has the security classification GÉANT Confidential, so further details of its contents cannot be presented here.

In Q2, significant recommendations regarding the regions that needed the most urgent attention were submitted to the SA1 Supervisory Committee and the Executive Committee for approval. These included solutions for:

- Leased circuits in the Iberian Peninsula.
- Milan–Marseille, Paris–Luxembourg, Brussels–Luxembourg, Frankfurt–Luxembourg, Geneva–Basel, Budapest–Zagreb and Milan–Madrid routes.
- Wavelengths to Turkey.

This led to a number of conclusions affecting the near-term connectivity procurement activity (reported in "DS1.2.1,3 Annual Procurement Report" [DS1.2.1,3]). The studies have also provided input to the major GÉANT transmission and switching equipment procurement [DS1.2.1,3]. Further recommendations will be implemented during Year 4. These include solutions for:

- Connectivity to Israel.
- The Baltic Ring.
- Connectivity in the UK/Ireland.
- Additional IP redundancy into Budapest.
- CBF in Poland involving DFN and CESNET.
- An alternative dark fibre path from Paris to Frankfurt through Luxembourg.
- The Hamburg point of presence (PoP).

2.3 GÉANT IP Design

2.3.1 Background

Work to redesign the architecture of the GÉANT IP layer started in Years 1 and 2, focusing primarily on short-term measures to accommodate the new GÉANT IP Peering service (see Appendix B.2.1 on page 14). The major part of the work, addressing an overall redesign of the GÉANT IP platform architecture and how it might change in light of the changes that will be made to the GÉANT switching platform as a result of the transmission and switching equipment procurement, was carried out in Year 3.

This activity gained significance in the context of preparing the Lot 2 (switching) part of the GÉANT transmission and switching equipment procurement Invitation to Tender (ITT). This is because the replacement of the current Time-Division Multiplexing (TDM)-based GÉANT Plus provisioning platform has always retained the option to leverage the installed base of GÉANT IP. The work has resulted in an architecture that in turn translated into explicit hardware capacity requirements for equipment procurement Lots 1 (transmission) and 2. The resulting plan will be refined in the light of the outcome of the Lot 2 procurement and ongoing discussions with the selected supplier. Accordingly it has only been disseminated and discussed amongst a limited group of people (those within SA1, procurement supervisory bodies including the Executive Committee and members of the NREN Policy Committee).

2.3.2 Design Document

The document “New GÉANT Network Design (Packet Transport & IP Layer)” [GN3-12-148] presents the high-level design of the new GÉANT packet transport and IP layers and the principles upon which it is based. It also describes the designs of the various stages through which the network needs to pass to get from the present day through the period of migration to the fully migrated (and converged) final design, currently expected to be achieved around Q2 2014 (i.e. about one year after the rollout of all the new equipment has been completed).

The document consists of the following sections:

- Introduction.
- Current Architecture – lists the salient features of the current network design that are of relevance.
- Principles of New GÉANT Architecture (including transmission layer).
- Principles of Migration Methodology – including exceptions, and pros and cons.
- Migration Stages – a high-level statement of the migration plan to get from the current network infrastructure to the fully migrated (and converged) goal.
- PoP Designs – principles governing the new designs of GÉANT PoPs and associated service capabilities in the various types of GÉANT PoP.
- GÉANT Services – briefly describes how the current GÉANT service portfolio will be mapped to the new network architecture.

The document has the security classification GÉANT Confidential, so further detail cannot be provided here.

2.4 Additional Access Points

A third area of activity in Year 3 has been to consider in detail options for realising additional network access points (AAPs) in the candidate locations identified in the deliverable DS1.1.1,2 “Final GÉANT Architecture” [DS1.1.1,2]. The most notable of these locations was Hamburg. This entails exploring availability of metro area fibre infrastructure to connect to NREN locations in the city, considering additions to and/or relocation of DANTE-managed sites, equipment needed (e.g. metro Wavelength-Division Multiplexing (WDM) equipment) and how any solutions are to be operated. This work is ongoing.

Further AAP options (e.g. Marseilles) have been discussed in the regional studies and associated report.

2.5 Near-Term Capacity Planning

As covered in [DS1.1.3,1] and summarised in Appendix B.2.1, the IP Layer Study that was conducted in Year 2 concluded that the peer network traffic matrix should be reviewed after the peering trial, begun in Year 2 Q2, had been operating for a while, when its impact on the GÉANT IP backbone would be evident. This review took place in Y3. As a result, backbone trunk upgrades have been performed to accommodate traffic growth, part of which is attributed to the addition to the core traffic matrix of the peering traffic and its ongoing growth. The upgrades are summarised in Table 2.2 below.

Month	Trunks	Upgraded To
April 2011	AT-IT, DE-CZ, AT-CZ	20 Gbps
August 2011	HU-CZ	20 Gbps
December 2011	DK-DE, HU-RO	20 Gbps
January 2012	NL-DK	20 Gbps
February 2012	AT-HU, HU-BG	20 Gbps
March 2012	CH-FR AT-HU	30 Gbps 20 Gbps

Table 2.2: Backbone trunk upgrades during Year 3

The peer network traffic matrix will continue to be reviewed in Year 4 as part of Operations’ regular near-term capacity planning activity.

3 Conclusions

In the original programme of work as described in the GN3 Technical Annex, SA1 Task 1 was expected to run only during the first two years of the project and to stop at the end of Year 2. This was because much of the resource allocated to architecture development was then expected to move to procurement-related activity (under the auspices of SA1 Task 2). To this end, the Year 3 plan for Task 1 foresaw the use of a limited amount of manpower to complete activities outstanding from Year 2, namely the regional connectivity strategy studies, redesign of the GÉANT IP layer architecture, the additional access points (AAP) study, and near-term capacity planning.

The regional connectivity strategy studies are largely complete, and a consolidated regional studies report has been produced which has provided essential input to the near-term connectivity procurements undertaken during the year. The report is a living document and as such will be subject to revision as and when more information regarding certain regions becomes available. In addition, further studies will be undertaken during Year 4.

Redesign of the GÉANT IP layer architecture is complete, and the resulting document was key to preparing the Lot 2 section of the transmission and switching equipment procurement ITT and to identifying explicit hardware capacity requirements for both Lot1 and Lot 2. The plan will be refined in the light of the outcome of the Lot 2 procurement and ongoing discussions with the selected supplier.

Detailed consideration of additional network access points and near-term capacity planning are ongoing.

Work items that will be continued and/or carried out in Year 4 (in line with the recent finalisation of the Year 4 work plan [GN3-11-356]) include:

- Ongoing updates to the regional connectivity strategy studies (including continuing to seek new opportunities for CBF solutions).
- Review the GÉANT IP backbone architecture.
- Develop an overall GN3 testbed strategy and plan.

  The work will be supervised by the SA1 Supervisory Committee (SA1 SC, which is already considering requirements for testbeds to support optical networking R&D, ongoing development of the GÉANT backbone and multi-domain services development and deployment), and will require input from other GN3 Service Activities and Joint Research Activities.
- Analyse the possibilities of brokering commercial cloud services for the NREN community.

In early 2011, the SA1 SC requested a paper explaining the concept of an Open Lightpath Exchange (OLE) and including a proposal for an OLE deployed under the GN3 umbrella. NORDUnet was commissioned to undertake this task. By the end of Year 3, both the SA1 SC and the Executive Committee had approved the establishment of a prototype OLE in London. Further development of a high-level design of an OLE will be done by SA1 T1 under the guidance of the SA1 SC early in Year 4.

Appendix A Summary of Work Conducted During Project Year 1

The work conducted during Year 1 was reported in deliverable DS1.1.3,1 and is summarised here.

Preparatory work actually commenced before the GN3 project started. Specifically, the first of a series of consortium-wide “Architecture Workshops” was held towards the end of 2008. This was followed by another four workshops during Project Year 1.

The topics presented and discussed in these workshops were wide-ranging, and included: service aspirations; forecasts of backbone capacity requirements; the state of play of a number of relevant telecommunications and networking technologies; operational aspects; the possibilities for exploiting “IP peerings” with Internet content and service providers; global connectivity; and experiences of trying to utilise customer/partner connectivity resources. Details of the workshops and a summary of some of the conclusions that were drawn can be found in deliverable “DS1.1.1: Report on the Architecture Backbone Study” [DS1.1.1].

Because it took much longer for the architecture workshops to run their course than was originally anticipated, it took longer for the detailed analysis work of SA1 Task 1 to get fully started and accordingly DS1.1.1 was much less conclusive than was originally intended. “DS1.1.2: Final GÉANT Architecture” was introduced as a new Y2 deliverable as a result, The delay in establishing the architectural blueprint in turn delayed the equipment and connectivity procurements. However, the eventual timing of the procurements, which were begun in the second half of Y2, means the project can benefit from the increased maturity and improved pricing of 100 G technology, while maximising the value of equipment purchased in 2005.

One piece of work that was done during Year 1 was to draw up a list of potential new backbone service offerings and service features [GN3-09-256] that could then be used as the basis of the method by which many Task 1 analyses were to be conducted during Year 2.

Appendix B Summary of Work Conducted During Project Year 2

The work conducted during Year 2 was reported in deliverable DS1.1.3,2 and is summarised here.

By the beginning of Year 2, SA1 Task 1's work plan consisted of three sets of sub-tasks focusing on:

- An information-gathering exercise to determine the state of play and market conditions for the supply of advanced optical transmission and switching equipment for the GÉANT backbone.
- Current backbone studies. Investigations into optimising the current backbone IP layer design, the physical layer and the inclusion of cross-border fibre (CBF)-based transmission services.
- Pre-procurement market studies.

Other key areas of work were:

- *"Final GÉANT Architecture"* deliverable.
- Procurement plan.
- Regional connectivity strategy studies.

B.1 Information-Gathering Exercise

The scope of the information-gathering exercise, which was conducted through the issuing of an RFI, was to cover the optical transmission and switching equipment of the GÉANT backbone. A Prior Information Notice (PIN) was published in November 2009, and a Request for Information (RFI) issued during Q4 of Year 1 to the 20 companies (equipment suppliers, value-added resellers (VARs) or operators) who responded to the PIN. Written responses to the RFI were received from 11 companies. Of these, two contained information about the same supplier's equipment; dealings with these two respondents were therefore subsequently merged. As a result, a total of 10 meetings were held and various follow-up interactions conducted. The findings from these meetings were analysed and a summary of the results of the RFI exercise prepared for consideration by the SA1 Supervisory Committee (SC).

B.2 Current Backbone Studies

Alongside the RFI process (and interacting with it), another set of sub-tasks focused on studying other aspects of the GÉANT backbone: investigations into optimising the current backbone IP layer design, the physical layer (with a view to proposing options for the improvement of overall network resilience and convenience of physical access); and the inclusion of cross-border fibre (CBF)-based transmission services.

B.2.1 IP Layer Study

The first study looked at possible optimisations of the current backbone IP layer design, especially with an eye to supporting traffic distribution changes that might occur as the result of GÉANT establishing presence at European Internet exchanges (IXs) and establishing peerings with significant Internet content providers.

Some analysis of netflow data was performed to examine aggregated flows transiting GÉANT between Internet content and service providers and GÉANT NRENs. This was done as part of the work to prepare for the establishment of GÉANT presence in key European Internet exchange points, which also included producing a number of documents detailing the nature of the two-phase peering trial that DANTE began in Year 2 Q2. One of the conclusions was that no additional GÉANT IP backbone modifications were needed in advance of the start of the trial, over and above the capacity upgrades that were already planned. However, it was agreed at the time that the peer network traffic matrix should be revisited after the peering trial had been operating for a while, when its impact on the GÉANT IP backbone would be evident. This is one of the items that will be completed in Y3.

B.2.2 Physical Connectivity Studies

Two of the sub-tasks focused on the physical connectivity (fibre and circuit) infrastructure of GÉANT. The objective of one was to improve overall resilience by proposing some improvements to the physical topology; the other investigated the possibilities for opening up opportune additional access points to the GÉANT backbone. Examples include an examination of the GÉANT Points of Presence (PoPs) and their environs in and around Frankfurt am Main and Geneva and studying the possibilities of opening up additional GÉANT access points in locations such as Marseille and Hamburg. Various options were presented in deliverable “DS1.1.1,2: Final GÉANT Architecture” [DS1.1.1,2], the update to deliverable “DS1.1.1: Report on the Architecture Backbone Study”.

B.2.3 CBF-Mediated Connectivity Study

Another sub-task studied the use of CBF-mediated connectivity (i.e. managed-wavelength-style connectivity) for the provision of GÉANT backbone and access connectivity. The original technical-only scope of this piece of work was extended to include operational and financial aspects; as a result, this work now straddles the remits of SA1 Task 1 and Task 2 Procurement. In this context, the work has been assigned to a new Regional

Connectivity Strategy Studies sub-task that was introduced into Task 1 during the second GÉANT Symposium in Vienna in November 2010.

B.3 Pre-Procurement Market Studies

A final sub-task was concerned with "pre-procurement" market studies, mainly with respect to the supply of dark fibre in regions where GÉANT does not yet have fibre network presence. The study for the region with the highest priority – namely, south-east Europe or SEE – was completed in Y2 Q2. However, a later development in procurement strategy for SEE came about in Q3 when the plans for the SEELight project [SEELight] were discussed during the second GÉANT Symposium in Vienna.

B.4 Final GÉANT Architecture Deliverable

By Y2 Q2, SA1's work had progressed to the point where the deliverable "DS1.1.1,2: Final GÉANT Architecture" [DS1.1.1,2] could be produced. The deliverable presented architecture options and recommendations for the future network, taking into account current and future requirements (such as current architecture, services, quality, user requirements and capacity forecasts) and opportunities for improvement (such as those afforded by technology developments). It also described the architectural building blocks that can be used in different parts of the network, and described the key technologies involved, focusing on their practical implementation, as preparation for the procurement process, and on how they can apply to the GÉANT network and service portfolio.

The Executive Summary of the deliverable is provided in Appendix C on page 17.

In addition to the usual deliverable reviews (by a subject matter expert, policy reviewer and the Quality Assurance and Public Relations (QASPER) Committee), the report was reviewed and refined by a joint working group comprised of SA1 Task 1 and a number of individuals drawn from the SA1 Supervisory Committee. It was published on 18 January 2011.

The fundamental and wide-reaching nature of the aspects addressed in the deliverable unsurprisingly made it a challenge to achieve a consensus that could be neatly expressed as a set of recommendations. As a result, some of the conclusions drawn were necessarily less prescriptive than was originally expected. The most notable example is with respect to recommendations about the nature of the technology to be used in the future for the provision of the sub-wavelength grooming and switching platform (which provides GÉANT Plus service instances). Nonetheless, the majority considered there to be sufficient consensus to be able to enter a competitive dialogue procurement process.

B.5 Procurement Plan

Following the completion of the "Final GÉANT Architecture" deliverable, a procurement plan was produced [GN3-10-356]. This was a detailed project plan outlining the order in which various procurements for equipment,

connectivity and related services needed to be undertaken and the nature of those procurements, in so far as they were defined by the recommendations made in DS1.1.1,2.

To develop those recommendations and generate more specific conclusions regarding medium-to-long-term plans for GÉANT backbone connectivity, a plan was drawn up for a set of regional connectivity strategy studies. These are described in the following section.

B.6 Regional Connectivity Strategy Studies

[The regional connectivity strategy studies are described in Section 2.2. To avoid duplication, the information common to Years 2 and 3 is not repeated here.]

With respect to the SEE study, the strategy for 2011–'12 for this region was essentially established during the second GÉANT Symposium in Vienna, where it was agreed that the SEELight project is unlikely to yield, within the next two years, any CBF-based connectivity solutions that could be used to build GÉANT backbone links in the region. Given that the SEELight project is procuring dark fibre, it was thought there is little justification in the GÉANT project doing the same. DANTE has therefore already started a procurement targeting the re-procurement of the leased wavelength circuits in the region, with the expectation that substantive cost savings will be realised in the short term.

Appendix C Final GÉANT Architecture: Executive Summary

Appendix C is based on the Executive Summary of deliverable “DS1.1.1,2: Final GÉANT Architecture”. Links to subsequent chapters in the deliverable and to referenced sources have been removed.

The approach to GÉANT architecture planning takes into account the current architecture, both its design and the multi-domain and global context in which it operates, and the following aspects:

1. The contents of the GN3 white paper, which summarises the project’s vision, strategic objectives and guiding principles, and outlines the rationale for the GN3 structure.
2. The services offered to and required by the GÉANT user base, how they are expected to develop, and what quality levels are associated with them, taking into account the multi-domain nature of end-to-end service provision over the extended GÉANT service area.
3. An analysis of capacity demand evolution, taking into account historic growth and predictions of user demand.
4. An analysis of the technological options that exist to fulfil those services, complemented by an analysis of the availability and maturity of technology in the market.
5. An analysis of the underlying fibre infrastructure and topology to ensure optimal network resilience and performance at all levels.

   Three topological shortcomings have been identified: diversity of trunks into Geneva, trunks into Frankfurt, and trunks into Budapest. Three areas of enhancement have been identified: extension of the GÉANT fibre footprint, its rationalisation (where there are suitable options and circumstances that can allow this), and the addition of more meshing. The topology analysis also considered additional, building-diverse National Research and Education Network (NREN) access points, for example in Hamburg and Marseille, and adding fibre junction flexibility points.
6. Study of availability of infrastructure to augment the GÉANT dark fibre footprint.

With respect to defining possible generic approaches to the GÉANT architecture, three architectural components and possible implementation alternatives have been identified:

- Internet Protocol (IP) component.
- Switching component.
- Optical transmission component.

Each implementation alternative has been evaluated, for each service and overall, using a number of criteria, including reliability, user-network separation, maturity of technologies, and multi-domain deployment.

In summary, the study has confirmed a pattern of constant growth in the amount of IP traffic over the GÉANT network and in the number of high-capacity circuits dedicated to projects, and a requirement for more advanced services and functionalities in the areas of authorisation and authentication, security, monitoring, and dynamic provisioning to meet user needs. The technology has evolved since the implementation of the GÉANT2 network at the end of 2005, offering new optical equipment capabilities and switching platforms, and marking the decline of Synchronous Digital Hierarchy / Synchronous Optical Networking (SDH/SONET) and a ubiquitous acceptance of the Ethernet protocol. The increasing importance of data transmission for the research and education community is placing a greater importance on the resiliency and redundancy of the services. The requirement impacts the whole infrastructure, from ensuring diverse physical routes to diverse fibres to the logical topology of the IP network.

The study has also confirmed that the hybrid infrastructure at the core of the GÉANT network represents a valid building block and provides the correct foundations for the next-generation infrastructure. This will be based on the fibre available to GÉANT, which has an enhanced role as a fundamental asset, and add the most appropriate switching layer at the packet and frame level on top of it. Figure C.1 below shows a high-level representation of the basic layers of the new architecture; the common functions of monitoring and authentication and authorisation are part of each layer and are depicted vertically for clarity and to show the required integration. Each layer has its own control and management planes (not shown); their integration between layers is subject to technological choices and ongoing research and development.

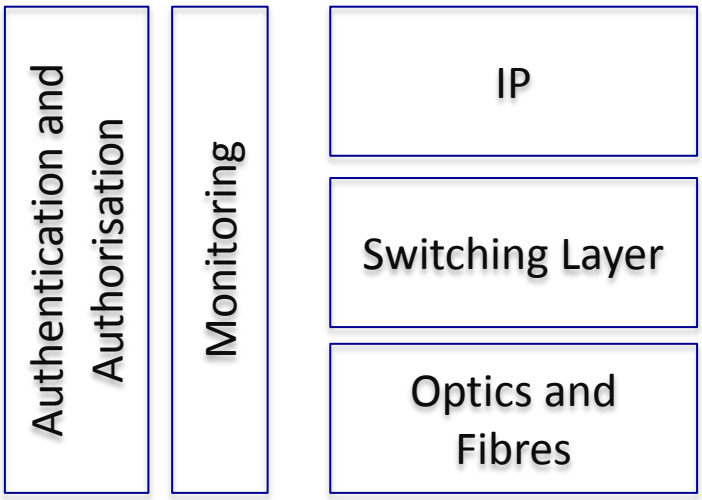

Figure C.1: Basic layers of the new GÉANT architecture

A number of important issues are common to all layers and require, in addition to analysis at the level of each individual layer, a solution that takes into account the interaction of all the layers. These are: resiliency and robustness to failures; fast recovery from failures; ease and speed of reconfiguration. In addition, the infrastructure should be transparent to the users and allow innovation. There are additional considerations and recommendations relating to: upgrading the current optical layer; enhancing the physical topology by increasing the meshing of the GÉANT fibre footprint, ensuring that the main connections run on physically diverse trunk

paths, and having more than one Point of Presence (PoP) in selected countries to open up additional access points for NRENs; switching layer; IP layer; and monitoring, authentication, authorisation and accounting.

The next generation network will be strengthened, at all layers, in the areas of resilience; agility and timely configurability; capacity; and interoperability.

From the technical studies conducted so far, there are clear preferences for the future GÉANT network, though these will be subject to further analysis:

- Availability of an agile transmission platform based on Reconfigurable Optical Add-Drop Multiplexers (ROADMs), to facilitate the resilience improvements needed, ensure the more efficient use of the topology and infrastructure, and facilitate additional access points.
- Availability of a logically separate switching layer, based on Ethernet over Multi-Protocol Label Switching (EoMPLS), carrier Ethernet (cE) or Optical Transport Network (OTN).
- Given the developments possible at the transmission and switching layer, there is now also the opportunity to review and optimise the IP layer.

The next steps are to compare the technical information and plans with vendors' contractually available solutions and reliable cost data. Further planning is required to devise an appropriate schedule for the staged approach(es) necessary to arrive at recommendations for solutions that may be implemented. This will include an assessment of the needs for further Request for Proposal work and/or commencement of some initial tendering phases. During this process the current implementations of NRENs' and international peering networks will be carefully considered to ensure that the largest number of services (including monitoring), may be seamlessly implemented. In addition, the project will monitor closely the needs of users with the most significant data-traffic demand, to ensure that the new architecture is able to meet their requirements in terms of both capacity and service provision.

The project will be cautious with regard to the possible complexities arising from novel technologies and it will ensure that the technologies selected involve low capital and operational costs, while maintaining the broadest possible compatibility and inter-operability with peering networks at all layers. Consideration will also be given to openness and interoperability. The availability of a greater number of fibres and wavelengths (either directly or provided by partners of the consortium) will help to keep complexity low, provide simpler solutions to resiliency, and enrich the services' capabilities.

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Glossary

AAP	Additional Access Point
CBF	Cross-Border Fibre
cE	carrier Ethernet
EoMPLS	Ethernet over Multi-Protocol Label Switching
IP	Internet Protocol
IX	Internet Exchange
MM	Man Month
NREN	National Research and Education Network
OLE	Open Lightpath Exchange
OTN	Optical Transport Network
PIN	Prior Information Notice
PoP	Point of Presence
Q	Quarter
QASPER	Quality Assurance and Public Relations
R&D	Research and Development
R&E	Research and Education
RFI	Request for Information
ROADM	Reconfigurable Optical Add-Drop Multiplexer
SA1	GN3 Service Activity 1 Network Build and Operations
SA1 T1	SA1 Task 1 Network Planning and Procurement Preparation
SA1 T2	SA1 Task 2 Procurement
SC	Supervisory Committee
SDH	Synchronous Digital Hierarchy
SEE	South-East Europe
SONET	Synchronous Optical Networking
VAR	Value-Added Reseller
WDM	Wavelength Division Multiplexing
Y	GN3 Project Year