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Deliverable DS1.1.3,2: Annual Report

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

Deliverable DS1.1.3,2

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Abstract

Second 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 second annual report, covering progress during Project Year 2 in the following areas: information-gathering exercise, current backbone studies, pre-procurement market studies, *"Final GÉANT Architecture"* deliverable, procurement plan, and regional connectivity strategy studies. It concludes with an assessment of the achievements and status of the Task as at the end of Year 2, and a summary of the work to be conducted in Year 3.

The purpose of the information-gathering exercise was to gain a better understanding of developments that have been made in advanced optical transmission and switching technologies since the original GN2 equipment procurement and, more importantly, how they could apply to the current GÉANT backbone. The emphasis was on technologies that are commercially available now, or will become so within one to two years. The exercise was conducted through a formal Request for Information (RFI) process, and successfully achieved its objective of allowing the project to understand what is technically possible now or will be in the near future, and how this can be applied to the GÉANT backbone.

Another set of sub-tasks focused on studying further aspects of the GÉANT backbone: the IP layer, the physical layer, and cross-border fibre (CBF)-based transmission services. Their objectives were to optimise the current backbone IP layer design, improve the overall resilience of the network infrastructure by proposing improvements to the physical topology, investigate the possibilities for opening up additional access points to the GÉANT backbone, and investigate the operational and financial implications of including CBF-based transmission services.

The purpose of the pre-procurement market studies is to gather market intelligence to facilitate the subsequent procurements. Those conducted in Y2 were concerned mainly with 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, south-east Europe (SEE), was completed in Y2 Q2. However, a later development in procurement strategy for SEE came about in Q3, as a result of which DANTE has already started a re-procurement of the leased wavelength circuits in the region, with the expectation that significant cost savings will be realised in the short term.

The RFI and backbone studies provided substantive inputs to the major architecture deliverable *"DS1.1.1,2: Final GÉANT Architecture"* [DS1.1.1,2], which itself represented a significant area of Task 1 work in Y2. The

deliverable establishes an architectural blueprint for the future GÉANT network and so informs the project's procurement, network build and operations activities as well as underpinning the delivery of GÉANT services. It 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 and on how they can apply to the GÉANT network and service portfolio.

The information in the *"Final GÉANT Architecture"* deliverable enabled the project to proceed with the long-term equipment and connectivity procurements. A detailed procurement plan was produced, outlining the order in which various procurements for equipment, connectivity and related services need to be undertaken. To develop those recommendations and generate more specific conclusions regarding medium-to-long-term plans for GÉANT backbone connectivity, a set of regional connectivity strategy studies is taking place, co-ordinated and largely conducted by groups of NREN experts from the relevant regions. These will identify potential solutions for connectivity and feed into the procurement process. At the time of writing (April 2011), the studies are expected to produce initial outputs by the end of Y3 Q1.

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. While Y2 has seen the completion of a significant network equipment information-gathering exercise (the RFI), along with a number of studies, and of the major architecture deliverable ([DS1.1.1,2]), there are a number of further or outstanding pieces of work that need to be completed before the Task can be fully wound up. In part this is because a new sub-task (the regional connectivity strategy studies) was started during Y2 Q3 and it took longer than anticipated to get the regional teams briefed and ready. Also, some additional sub-tasks came about as recommendations made in the conclusions of DS1.1.1,2. Completion of the outstanding sub-tasks will take place during Year 3. but at a much lower effort level than Y1 and Y2 (the estimated manpower required is about 20 MM), in order to conclude these remaining sub-tasks and provide the input to Task 2 that will help ensure the success of the major procurements now in progress.

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 GN3 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. A first annual report on the progress of this work during Project Year 1 was provided in deliverable DS1.1.3,1 [DS1.3.1,1]. This document is the second annual report, on progress during Year 2.

The document covers the following topics:

- Brief recap of work conducted during Year 1 (Section 2).
- Summary of work conducted during Year 2, covering the information-gathering exercise, current backbone studies, pre-procurement market studies, *"Final GÉANT Architecture"* deliverable, procurement plan, regional connectivity strategy studies (Section 3).
- An assessment of the achievements and status of the Task as at the end of Year 2 and a summary of the work to be conducted in Year 3 (Section 4).

An extended summary of the *"Final GÉANT Architecture"* deliverable is provided in Appendix A.

2 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.

3 Summary of Work Conducted During Project Year 2

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. A Prior Information Notice (PIN) was published in November 2009, 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, and a series of meetings begun with the 11 companies who submitted written responses to the RFI.
- 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.

This section summarises the Year 2 work in each of these areas.

3.1 Information-Gathering Exercise

3.1.1 Scope

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 and did not include the IP/MPLS routing equipment as it currently stands. Although one element of the RFI looked at realistic roadmaps towards convergence of network layer functionalities, this was focused more on convergence of transmission and switching.

3.1.2 RFI Respondents and Meetings

Written responses to the RFI document were received from 11 companies. Of these, two contained information about the same supplier's equipment (one was from the supplier itself and the other from a preferred channel partner for that supplier); 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, taking advantage of the opportunities presented by the attendance of many of the respondents at the WDM and Next Generation Optical Networking conference and exhibition held in Monaco in June 2010.

3.1.3 Analysis of Findings

The findings from these meetings were analysed in Q1 of Year 2. DANTE prepared a summary of the results of the RFI exercise for consideration by the SA1 Supervisory Committee (SC). In addition, individuals from 5 of the NRENs taking part in SA1 Task 1 signed the necessary supplier non-disclosure agreements (NDAs) (these were requested by four of the respondent companies) and so were able to review the RFI response material received by DANTE. These individuals also prepared summaries of their views of the RFI for the SA1 SC.

3.2 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.

3.2.1 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. Data showing aggregated traffic flows between GÉANT peers (GÉANT NRENs, other R&E networks, upstream commodity providers, etc.) was examined, but was concluded to have produced limited substantive results from which to determine the necessity for any short-term modifications either to the logical IP topology or to the topology of the underlying physical infrastructure. Further netflow analysis was therefore performed, this time between source and destination networks rather than directly peering networks. The purpose of the analysis was 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

(these upgrades have since been reported in the *"Monthly Service Summary Report"* series of deliverables [DS1.3.1,20-24]). 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 (see Section **Error! Reference source not found.** on page **Error! Bookmark not defined.**).

3.2.2 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".

3.2.3 CBF-Mediated Connectivity Study

Another sub-task has 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 (see Section 3.6 on page 9).

3.3 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. This resulted in a draft report covering fibre infrastructure and its supply in Bulgaria, Romania, Serbia, Macedonia and Montenegro. The market intelligence in this report was expected to be of great help to those conducting future procurements for dark fibre in the SEE region. 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.

3.4 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.

A brief summary of the contents of this deliverable is provided below and, in addition, the Executive Summary of the deliverable is provided in Appendix A on page 13.

The deliverable included material on:

- Expected service portfolio support requirements (including service quality features and capacity forecasts).
- Relevant transport technologies derived from JRA1 Future Network work and the transport equipment RFI conducted within SA1.
- Analysis of the resilience and diversity aspects of the network associated with the physical infrastructure.
- Analysis of the various options for the combinations of different transport technologies.
- Recommendations for:
    - GÉANT fibre footprint expansion plans and modifications.
    - Potential sources of some of the connectivity that will still be based on managed bandwidth and other associated support services (NREN resources).
    - Preferred transport technology combinations.

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.

3.5 Procurement Plan

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

3.6 Regional Connectivity Strategy Studies

The regional connectivity strategy studies are being 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 being identified by the regional teams and, if applicable, compared with NREN CBF offerings (in accordance with the capacity acquisition process currently awaiting GN3 Executive Committee approval). 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. There will be a separate procurement for connectivity and for equipment but both will require input from the regional studies at the appropriate time. At the time of writing (April 2011), the studies are expected to produce initial outputs by the end of Y3 Q1.

The SA1 team will consider the recommendations provided by the regional study groups and review them for issues such as compatibility across the whole network. This may lead to further iterations before a final solution can be 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 3.1 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

Region	Current GÉANT PoPs Affected	Co-ordinating Partner
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 3.1: Structure of regional connectivity strategy studies

In addition to these geographically based connectivity studies, there is also a more technologically focused study on Reconfigurable Optical Add-Drop Multiplexers (ROADMs) in fibre junctions, which is being co-ordinated by CESNET.

With respect to the SEE study, the strategy for the next two years 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.

4 Conclusions

Project Year 2 saw the completion of a significant network equipment information-gathering exercise (the RFI) along with a number of other sub–tasks, all of which provided substantive inputs to the major architecture deliverable ([DS1.1.1,2]) which was also completed during Y2 by SA1 Task 1 in conjunction with the SA1 Supervisory Committee. These other sub-tasks were mostly focused on the study of various aspects of the GÉANT backbone and included 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. In addition, a pre-procurement connectivity market study, focused on the SEE region, took place.

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 project years and to stop at the end of Project 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). At the time of writing (April 2011), most of the work that was due to be completed during Project Year 2 in preparation for the major procurements that are now getting under way has been completed. However, there are a number of further or outstanding pieces of work that need to be completed before Task 1 can be fully wound up. In part this is because a new sub-task (the regional connectivity strategy studies) was started during Y2 Q3 and it took longer than anticipated to get the regional teams briefed and ready. Also, some additional sub-tasks came about as recommendations made in the conclusions of DS1.1.1,2. These work items are outlined in the Final Considerations and Next Steps section (9.3) of DS1.1.1,2 and are as follows:

- Study of the introduction of optical agility into the transmission platform using ROADMs (as already mentioned in Section 3.6 above).
- Study of the various technologies that are likely to allow the realisation of the next generation of the GÉANT Plus service provisioning platform (to be much more Ethernet-centric than the current incarnation of the platform).
- Study of the IP layer in GÉANT (with a view to proposing ways of optimising its architecture).
- Further work on estimating migration costs (the main cost here – and one that will be difficult to estimate – would be the potential migration from the incumbent transmission platform to another in the event that it is replaced).
- Completion of the regional connectivity strategy studies.

This means that Task 1 will continue throughout at least the first two quarters of Year 3, but at a much lower effort level than seen in project years 1 and 2 (the estimated manpower required to complete this work is about 20 MM), in order to conclude these remaining sub-tasks and provide the input to Task 2 that will help ensure the success of the major procurements now in progress.

Appendix A Final GÉANT Architecture: Executive Summary

Appendix A 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 A.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.

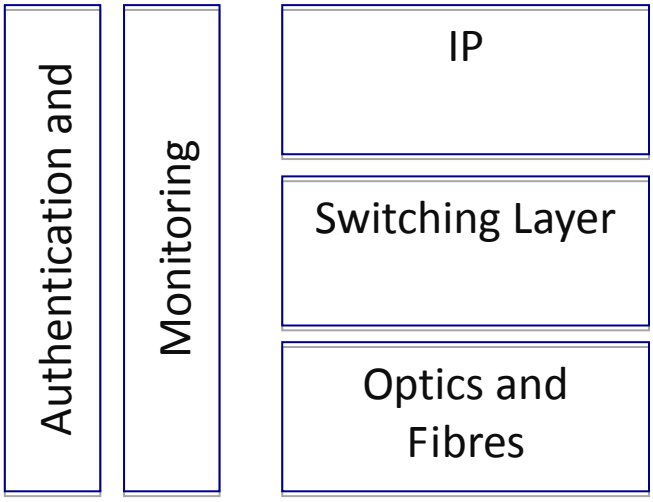

Figure A.1: Basic layers of the new GÉANT architecture

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.

References

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Glossary

AAP	Additional Access Point
CBF	Cross-Border Fibre
cE	carrier Ethernet
EoMPLS	Ethernet over Multi-Protocol Label Switching
ILA	In-Line Amplifier
IP	Internet Protocol
IX	Internet Exchange
JRA1	GN3 Joint Research Activity 1 Future Network
MM	Man Month
MPLS	Multi-Protocol Label Switching
NDA	Non-Disclosure Agreement
NREN	National Research and Education Network
OTN	Optical Transport Network
PIN	Prior Information Notice
PoP	Point of Presence
Q	GN3 Project Quarter
QASPER	Quality Assurance and Public Relations
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