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Deliverable D3.7
Requirements Commentary on GÉANT Services

Deliverable D3.7

Abstract
A service requirements analysis to improve understanding of how and where users will be working in five years' time and details what GÉANT will need to be doing in order to meet their expectations.

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Executive Summary

As part of Networking Activity 3 (NA3) Partner, User and Stakeholder Relations, this deliverable describes feedback about GÉANT services received from multiple stakeholders and sets out recommendations to be considered by the GÉANT project to meet the ongoing challenges of providing services.

The information gathered in this review will help GÉANT to better understand how and where users are likely to be working in five years' time, and how GÉANT could meet (and exceed) user requirements. This input will feed into ongoing network and service portfolio planning work.

For the purposes of this document, 'users' are National Research and Education Networks (NRENs) and international research projects, who directly consume GÉANT services, as opposed to those institutions and individuals, 'end users', who benefit from GÉANT services via their domestic NREN.

The recommendations presented here are based on information gathered from key stakeholders in GÉANT, complemented by project-related data. A major input comes from discussions with the European NRENs that are partners in the GÉANT project (a list is provided in Appendix A). This is supplemented by an analysis of discussions with NRENs in other world regions and representatives from major European science projects.

The study recognises that requirements and constraints from stakeholders outside of those listed above will also have an impact on GÉANT's planning.

A number of conclusions and recommendations are presented to act as guidance for the development of future GÉANT work, including:

- Development of training to include international partners as well as European NRENs.
- Enhancement of communication of best practice regarding software development
- Extension of Trust and Identity (T&I) outreach activity to provide 'on the ground' technical support for International Research Projects.
- Continued work to develop a greater process automation for services.
- Development and deepening relationships with international science projects and e-Infrastructure projects.

Promising work has already begun in the current GN4-2 project targeting many of the areas addressed in this report.

1   Introduction

The National Research and Education Networks (NRENs) participating in the GÉANT project (GN4-2) recognise the need for future service development. In the 2017 annual NREN Satisfaction Survey, 93% of respondents stated that the GÉANT service portfolio met their current needs. However, this figure dropped to 73% of respondents when the question expanded to cover a five-year horizon.

In order to gain a better picture of future service requirements input has been sought from stakeholders within GÉANT. This deliverable is based on a range of this input, including:

- The European NRENs who participate in the GÉANT project, and who use and help develop the current service offering.

- International peers of GÉANT operating in other world regions, offering similar services to the Research and Education community and who cooperate with GÉANT to provide service on a global scale.

- International research projects that are major users of research network infrastructure on a pan-European and a global scale. These include e-Infrastructure projects that offer a variety of ICT services and use GÉANT as a delivery mechanism, as well as research projects that are consumers of GÉANT services and network capacity.

- Leaders and opinion formers active within the GÉANT project who have practical experience of the service development process. Their views tended to range widely over multiple topics and are reflected throughout Section 3 and 4.

Developments and views from other stakeholders, namely the European Commission and telecommunications hardware vendors were also considered.

The European Commission is a major funder of the GN4-2 project, as it has been for previous generations of pan-European projects associated with Research and Education networking for many years. It also funds a broad range of Research and Development work through its framework programs.

Through regular communication channels with the EC, GÉANT already has a good understanding of the likely requests, but some EC requests may strongly impact GÉANT (the GÉANT project and the organisation). To be prepared for new initiatives and requests from the EC, GÉANT could define its general policy as part of its agreed strategy and maintain its positive consultation with relevant parts of the EC.

As suppliers of the global marketplace for telecoms service providers, hardware vendors are a key group and their development plans will have a major impact on the future direction of global network services. Future GÉANT services need to be realisable, based on the technology that will be available. An extensive analysis of the implications of these developments has been carried out in the Network Evolution plan, undertaken by Service Activity 1 (SA1) in the GN4-2 project based on interviews with vendors and its own analysis.

This understanding of vendor development plans in the medium-term will enable GÉANT to consider new strategic options for network architecture. These could yield substantial financial savings and offer greater flexibility in terms of vendor choice, as well as facilitating the introduction of new services. From the analysis carried out of the current and possible future strategies, GÉANT should examine new architecture approaches and pilot them in a lab environment as proof of concept to ensure high levels of reliability can be maintained and procurement can remain effective.

This document includes the following content:

- Section 2 sets out the methodology applied to the collection of service requirements.
- Section 3 presents views of the GÉANT partner NRENs, and it also includes details of feedback shared by partners outside Europe.
- Section 4 describes the projects involved, including major science contributions and European e-Infrastructure projects.
- A list of recommendations for future developments in included in Section 5.

2 Methodology

This study is based on the views and opinions of stakeholders, complemented by project-related data routinely collected as part of the ongoing GÉANT project. The focus of the feedback has been on a general view of future services and service requirements.

The main input to this work was via a series of over 100 semi-structured stakeholder interviews coordinated by GN4-2 Networking Activity 3 task leaders. These interviews took place mid-2017. NRENs, international projects, leaders and opinion formers responded to a set of interview topics which were adapted by interviewers as appropriate during meetings to match interviewee expertise. Respondents contributed on a range of topics, including: cloud services, trust and identity (T&I), security and network services. Stakeholders' development plans and future challenges were also discussed. In particular, NRENs were asked for a 'wish list' of topics that they thought most relevant to future plans in the next five years (highlights from these responses are presented in Appendix A). Bilateral meetings with stakeholders were supplemented by group discussions during Task Force and Special Interest Group meetings involving multiple NRENs.

This semi-structured style of qualitative data capture was selected in order to provide richer data than what could be obtained through a structured interview alone. With greater flexibility to clarify or expand on a stakeholder's answers, the interviewer was able to explore specific situations and requirements.

Data gathered within the GN4-2 project has also been used to complement this write up. Information from the *GÉANT Compendium of National Research and Education Networks in Europe* [Compendium], work on the GÉANT Service Portfolio, and the effort relating to Service Activities and Joint Research Activities have added further insight to requirements gathering – offering quantitative data sets to cross-reference comments, where appropriate.

Inherent in interview-based situational analyses are the opinions of those interviewed. In addition to the aforementioned supplementary data, the following sections describe in more detail the characteristics and service offerings of the stakeholder groups defined above so that context is clearly signposted. Their narratives and views are analysed by summarising the inputs that came from the individual discussions with group members.

Each section presents significant findings and Section 5 summarises the main points that emerge from this work and makes further recommendations that could be used as guidelines for future planning.

3 Partners

3.1 European Partner NRENs

The European NRENs participating in the GÉANT project are the driving force behind the collaboration. Interviews were carried out with 31 NRENs to gain an understanding of their future requirements, as well as their ongoing commitment to the GÉANT collaboration. The interviews were based on a common template that considered a number of existing areas of service, including: network, trust and identity, security and cloud services. The interviews also sought to gather more general opinions about the future direction of development efforts, as well as the NRENs' views about current work. Alongside these interviews, Task Forces and Special Interest Group meetings were held, where several NREN representatives discussed the areas relevant to their remit.

This section provides a summary of the main findings and explores a number of points that can be derived from the interviews.

The NRENs involved in the GÉANT project are a very heterogeneous group, with a range of characteristics, for example:

- Country size – The smallest NREN represents a national population of less than half a million people. The largest represents over 80 million.
- Funding structure – NRENs are funded in various ways. Some receive all their funding directly from national government, others are funded entirely by their connected sites, while other funding models involve a mix of these two approaches.
- Organisational structure – Some NRENs are independent commercial organisations, while others are directly or indirectly part of government.
- Service responsibilities – the user constituencies that NRENs serve vary considerably, for example:
  - Some serve primary and/or secondary schools, while others do not.
  - Levels of user interaction vary; some have little or no direct interaction, while others interact with user institutions, research groups or institutions.
  - In terms of networking, some NRENs directly connect institutions, while others connect institutions via regional networks.

Given such diversity, it is unsurprising that there are a range of views expressed regarding the future direction of GÉANT during the next five years.

3.1.1 Summary of Interviews

As disparate views have emerged from the interviews with NRENs about their future development activities, it has not been possible to draft a unified approach. However, there are a number of key themes articulated by NRENs, with general agreement that cloud computing, security and trust and identity will remain relevant areas for future work. Four other areas have also emerged from NREN responses*:

- A number of NRENs agree that a training programme to gain experience and knowledge from practitioners in GÉANT would be valuable.
- Another concern articulated is the need for better communication of best practice among NRENs regarding their software development experience.
- Leveraging the event organisation and communication skills that exist within the GÉANT organisation to help NRENs with PR and communications.
- One interesting concept to emerge is the need for NRENs to develop greater process automation for managing their operations and customer contacts. Such process automation, which involves replacing manual processes, is often operated by engineers with systems based on user-friendly software interfaces. This enables users to better manage national and international services offered by NRENs, as well as offering NRENs efficiency gains.

    In a world where people are used to interacting with computers to acquire services, this is a natural area for development. This new area of study could support direct customer management of services, which, if implemented consistently across GÉANT, could allow for seamless service provision.

The following subsections deliver a summary of national NREN roadmaps and their wish list of potential GÉANT developments, generally, and in the areas of network, security, T&I, clouds and applications.

These summaries alone cannot exactly determine what the GÉANT project needs to do to meet NRENs' needs. A series of white papers proposing developments in specific areas are being used as inputs for future planning/discussion.

3.1.1.1 *Network and Network Services*

National Roadmaps

National infrastructures, in most cases, have been carefully set up or have plans in place to upgrade their core capacity and infrastructure to meet the anticipated demand. Only one or two NRENs expressed a lack of sufficient network capacity. Some smaller NRENs expressed an interest in investing in infrastructure and expanding their footprint.

Software Defined Networking (SDN) is a hot topic in the community, and some NRENs have already taken on the early adopter role exploring how they can introduce SDN into their network. The majority of NRENs expressed an interest in learning what others are doing but believe that it is too early for their own investment.

The MD-VPN service, developed within the GÉANT project, has experienced a significant uptake and positive feedback by the NRENs through the adoption of the service by PRACE for its pan-European network [MD-VPN].

GÉANT Wish List

Cross Border Fibre (CBF) and the utilisation of existing NREN infrastructure is widely considered as a beneficial addition to reduce network costs. However, an all-in approach is generally not favoured, as some NRENs made it clear that they do not have spare capacity. Other NRENs are limited to provide CBF due to governance restrictions.

Those NRENs attentive to automation and SDN expressed an interest in GÉANT's orchestration and deployment facilities to make it easier and faster to satisfy requests for network configuration changes, even temporary ones. Such systems could be extended to all network services (see Appendix A for direct quotes/NREN feedback).

3.1.1.2 *Security*

National Roadmaps

Security was mentioned as a very important topic for all NRENs, which is a significant change to previous years in terms of awareness and visibility. All NRENs expressed interest and the majority claim to be very much engaged in this area through their own services, outreach activities to their users, or actively participating in knowledge exchange, e.g. TFs/SIGs.

Many NRENs take pride in their own security expertise. Some strategically focus on large teams of experts (and their security expertise) as a competitive advantage over commercial providers.

Those NRENs using the GÉANT Firewall on Demand (FoD) are very satisfied with the service and would welcome an expansion of features.

GÉANT Wish List

There is great interest in pan-European knowledge exchange on security, including support of national deployment of GDPR (e.g. supported through a Task Force).

Some specific areas noted were: GÉANT secure Clearing House, DDoS reporting and pan-European dashboard with statistics. Network monitoring software NetFlow was also of interest to NRENs to provide data for increased security.

3.1.1.3 *Trust and Identity*

National Roadmaps

A couple of NRENs had clear ideas regarding their national roadmap to further develop and enhance T&I work. Topics mentioned included the extension of features, the introduction of group management functions and lifetime-ID.

The picture drawn by many smaller NRENs was that they struggle to convince their connected institutions of the benefits of federations and joining eduGAIN. The stated reason for this was a lack of services they can offer. Another challenge for a successful adoption is the lack of required skills within the NREN. It will be important to support new skill development in future work, such as the GÉANT Academy programme mentioned in Section 3.1.6.

eduroam is a key service of interest in the smaller NRENs; many plan to expand their footprint. Some are struggling with manpower constraints and would benefit from technical support (on-premises) to install and deploy eduGAIN – and, in parallel, to help promote eduGAIN and eduroam.

GÉANT Wish List

Most NRENs have successfully adopted the GÉANT services of eduroam and eduGAIN, and are very satisfied with the services and their adoption.

Some NRENs also expressed a strong interest in GÉANT taking on a more active role in service provision and support e.g. establishing an operations function, including SPOC for technical issues.

More support also for promotional activities within the country, is desired.

3.1.1.4 *Clouds*

National Roadmaps

Many NRENs have their own cloud offerings, which are more or less successful. The most successful approach so far appears to be providing a data storage and compute service for data with high security requirements (complementing commercial offerings). The end-user demand varies between countries.

Overall, business models for take-up and management of cloud services still need to be worked out, particularly to enable the take up of the IaaS framework (scope and maturity levels differ here). This is a new area for all NRENs and requires a significant shift in operations. Some NRENs cannot benefit from this framework, however, as they are either not a separate legal entity (attached to a university or government ministry) or are not part of the European Union.

GÉANT Wish List

There is a demand for more technical support in the adoption of cloud services (so far only commercial aspects are covered through the GÉANT project).

Joint framework agreements are considered beneficial and most NRENs stated they would be interested in further agreements of this kind. However, it was pointed out that the negotiated terms and conditions are not favourable in all countries, as some NRENs are able to negotiate better prices nationally and NRENs in non-EU countries may not be eligible.

More joint procurements are desired (depending on an NREN's individual needs) using GÉANT expertise, financial services and technical support.

3.1.1.5 *Applications*

National Roadmaps

Only a few comments were received in this area, with no clear emerging trend. Some individual services were named, e.g. data analytics offerings, centralised Web and mail hosting, and a platform for online exams. Some NRENs are offering video web-conferencing – but share the opinion that all systems have flaws.

GÉANT Wish List

The main request for new applications was that any developed service should be easily available, immediately installable and not require a lot of effort to support.

The GÉANT Testbeds Service (GTS) received a few comments and is currently under consideration by NRENs.

3.1.1.6 *General Comments*

National Roadmaps

General comments were received highlighting the interest in more engagement with end users and researchers.

There are NRENs with strong research engagement activities. They usually operate either under quite flexible funding and business models, are parts of the university (often initiated/run by university staff) or are funded by the respective institutions (e.g. National Science Council).

Other NRENs struggle to reach out to end users, because their primary customers are the university IT centres and/or they are lacking manpower resources. NRENs with university IT centres as customers/owners stated that they struggled to reach out to end users (students, researchers) to assess requirements and drive service adoption. In turn, they also believed their role to be relatively unknown to their end users.

Many NRENs invest in expanding their customer base (either self-driven or initiated by government). Different approaches are being pursued, including: expansion to schools (mostly if fully owned by government), public administration (health) or more engagement with commercial R&D.

The network connectivity to the international partners remains a real added value of the GÉANT network.

GÉANT Wish List

There is continued demand for greater knowledge exchange and transfer. Task forces, special interest groups (SIGs), Service and Technology Forum (STF) are considered to be valuable platforms. NRENs generally would like to see more of these, especially for support of short-term initiatives (activities with less than a one-year duration) to be able to address specific questions), along with an upgrade of the partner portal for NREN-specific service information.

As an extension to the above, both small and larger NRENs expressed the need for increased training for the community to help bridge the digital divide and bring new talent into the community to drive the future. Such training was mentioned in future GÉANT work to develop a "GÉANT Academy" for skills development and the demand for a varied approach (broad awareness-building on new developments and how these could be implemented, as well as very tailored support for individual NRENs to e.g. support them in taking on a specific service).

Many NRENs expressed interest in 'white labelled' (basic) service information (produced by one company but rebranded as another) to allow national adoption. These NRENs considered up-to-date service information was lacking and their product management and marketing were perceived as non-existent.

The demand for more legal support and general reassurance was a popular new topic during the feedback discussions. Some larger NRENs have dedicated legal staff supporting their operations and service/network developments. The integration of cloud services and adoption of the IaaS framework poses a legal challenge for many countries e.g. integration into business models, but also compliance with national and sometimes federal regulations. Developers desired legal support and assurance in the service development within the project. The effects of the EU General Data Protection Regulation (GDPR) on NREN services and operations was also mentioned in many cases.

3.1.2   Service Themes

Views about future developments, expressed in the NREN interviews, vary considerably. Some see GÉANT as a vehicle for shared development. Others wish to see individual NREN developments accepted by GÉANT and adopted more widely throughout the partnership. These divergent views underline the need for the structured approach to defining the future service development that GÉANT is seeking to achieve.

Several general themes regarding GÉANT service portfolio management were apparent during NREN discussions and are noted here:

- **Analyse past service successes based on user take-up**: Through discussions it was apparent from some NREN comments that there is dissatisfaction with the results of earlier GÉANT developments or else preference for the use of commercially available products. To explore this in greater detail, it is recommended that feedback regarding historical developments be further analysed as part of a systematic investigation of the success of such developments, based on user take-up. This work could be used to improve the future development process to ensure that it meets genuine demands, learning from experience of earlier developments to better target development resources and improve take-up of development results.

  The GÉANT Compendium and annual GÉANT NREN Satisfaction Survey provides a qualitative analysis of services from an NREN service provider perspective but the project could also put in place routine measurements of service usage and employ them to assess service viability.

- **Get development and adoption commitment early**: One respondent was hesitant to look at the broader adoption of GÉANT services due to a perceived lack of sustainability. Questions were also asked about future service support. To address this future uncertainty, GÉANT will

need to continue to strengthen NRENs' levels of commitment (all NRENs, or a subset or developers).

GÉANT could consider making future developments dependent on an initial commitment to implement the results and to continue to allow subsets of NRENs to develop jointly, on the assumption that not all services developed in the GÉANT service area will be of benefit to all GÉANT NRENs. This could provide greater impetus to implement the resulting services. The business case process used within GÉANT goes some way towards ensuring viability of service developments, but it does not commit NRENs to implement services developed by GÉANT.

In addition, during the interviews, some NRENs indicated a lack of development resources that they could easily commit to GÉANT. It is apparent from analysis of the development resource which NRENs have committed to the project, that there are significant variations in effort provided. The business case process could be used to determine whether a development or major enhancement is viable prior to commitment of development resources i.e. as with adoption of service, identify and guarantee availability of development effort.

- **Enhance transition to service process**: Historically, there has been a strong focus on the technical resources needed for development and on the technical challenges to be overcome. As a result, many historical developments have reached a proof of concept stage but have not moved to a supported operational service. A stronger emphasis could be placed on issues such as service rollout and service support by ensuring that the transition phase between development and operational teams is well planned, the service needs are clear, and the ability of development teams to meet them is also clear.

3.2   International Partners

GÉANT's international partners outside Europe are vital for the global reach of R&E networking. Their service co-operation with GÉANT provides access to researchers around the globe. The partners represent a mixture of national R&E networks similar to European NRENs and regional networks similar to GÉANT. Most of the regional networks have been developed with the assistance of European Union aid-related funding. The following table sets out the details of the partner networks with whom discussions were held.

Network	Type of Network	Area Covered
UbuntuNet	Regional	East and Southern Africa
WACREN	Regional	West and Central Africa
RedCLARA	Regional	Latin America
CANARIE	National	Canada
Internet2	National	USA

Network	Type of Network	Area Covered
CERNET	National	China
NKN	National	India
ASREN	Regional	Arabia
SingAREN	National	Singapore
NIIv2	National	Japan
ESNET	National	USA

Table 3.1: International partner networks and areas covered

The environment in which the networks operate varies considerably. Some networks operate in a liberalised telecommunications market where access to bandwidth and technology is unconstrained by regulation or monopoly. They operate at a similar scale to GÉANT. This is generally true of the national networks. The regional networks are often much more constrained by funding and infrastructure availability. Thus, the issues raised by the networks depended to an extent on their own operational environment. There were some key messages that emerged and even mirrored experiences of European NRENs. Notably, these were:

- Several networks mentioned that funding was becoming an increasing challenge and there was a need to demonstrate improving value for money to both users and funding bodies.
- Trust and Identity (T&I) was mentioned as an important area for collaboration. It was noted that there was a need to develop T&I service usage as opposed to investing in additional development.
- Global R&E co-operation, particularly in science fields, demonstrate a need for common support and closer collaboration.
- There was a general recognition of the increasing importance of security and various development initiatives but no clear overall direction as far as security services and developments are concerned.
- There was a general request from those networks that are still in a developmental phase for capacity training on governance, policy, etc. and a request for experts from the GÉANT community to participate.

The International partners stated that the co-operation with GÉANT was vital to their own networking developments. In addition to the common issues raised by international partners documented above, a series of bilateral points were raised, which can be seen as business as usual.

4 Projects

There are a number of international collaborations, particularly scientific collaborations, that bring together researchers from around the world to work together on a common research topic. Examples include the fields of radio astronomy, particle physics, climate change and biology. Global co-operation is needed, in some cases, because the cost of experimentation is too great for a single country to want to pay, such as the case with the Large Hadron Collider (LHC). In other cases, cost plays a significant role, but it is the need to have experimental facilities sited in a particularly favourable geographical location that is a key factor (astronomy). A third rationale for co-operation is the need to have a common response to global challenges (climate change). Collaborations such as the HEP Council and IPCC are characterised by a single global governance and working methods that transcend national boundaries. The projects typically share significant quantities of data and wish to interact with Research and Education networking via a single point of contact. They also depend on consistent service provision. If consistent and homogeneous services cannot be acquired from NRENs, ICT capability exists within their projects to implement their own services, although there is usually a preference for acquiring, as opposed to building such services within their projects. These groups are referred to in this document as International Science Projects.

There is a second group of European projects that provide infrastructure and are concerned with service provision to the research community. These projects are based on the concept of providing shared ICT infrastructure, essentially centralised computing and storage facilities, which generally interact with GÉANT as a network service provider, enabling remote access from researchers to the centralised facilities. These are listed below and are referred to in this document as European e-Infrastructure projects.

The following section considers the challenges faced by each of these sets of projects.

4.1 International Science Projects

The following table lists seven areas of research and scientific collaboration, with whom discussions were held for this analysis. Interviews were carried out with representatives from each of these areas to understand future networking and services requirements.

Project Acronym	Area of Science	Location of Project Participants
HEP	High Energy and Particle Physics	Global
ITER/EuroFusion	Nuclear Fusion	Europe, Japan

Project Acronym	Area of Science	Location of Project Participants
ELIXIR/EMBL-EBI	Life science, Genomics, Bio-imaging	Europe
SKA, AENEAS, eVLBI	Radio Astronomy	Global
Extreme Light Infrastructure	Laser Physics	Europe
ESA	Space Research	Europe
EUMETSAT	Weather and Climate	Global

Table 4.1: Project representatives

These projects and collaborations are at various stages of development. The most mature, HEP, represents a co-operation that has continued for over 50 years, and is the biggest single user group of the GÉANT network in terms of data traffic. By comparison, the operation phase of the Extreme Light Infrastructure will commence soon (2018). The different areas are also users of different kinds of services, some of them focusing more on the network services, e.g. the HEP community, while others rely on above-the-net services, mainly T&I services, e.g. ELIXIR [ELIXIR]. The multi-country nature of the collaborations means that they look to interact with a single point of contact to support their collective research network needs. Key messages to emerge were:

- Network speed and quality is not perceived to be an issue. In fact, the reverse is true since many perceive the network as a ubiquitous and unlimited service.

- The total cost of ownership for storage is the top concern across almost all the data-intensive projects, even greater than the expected growth in data production.

- The projects foresee very significant data-flows between their connected sites: some of them are changing their computing model to rely more on the network transfers and/or computing power, and less on the storage capacity.

- There is real interest by some of the more mature projects for greater interaction with the network. This could be accomplished by gaining access to network statistics that can improve intelligence in data distribution models, or by influencing network configurations.

- GÉANT has a role in the T&I area by providing service solutions to individual communities within the R&E community worldwide. Several projects indicated that they would be happy not to have to commit this effort themselves. Where collaborations incorporate different institutions, respondents relayed that they are forced to create an additional IdP. This means that users need to create new accounts in this central IdP and cannot rely on the credentials of their home institution.

- The projects expressed an interest in cloud-based services and questioned if/how GÉANT activities in this area could fulfil their needs by providing cost-effective access to resources. Strong concerns emerging in relation to adoption of cloud resources included:

  ○ Procurement – the business model and supply procedures of most cloud providers does not fit with a project's funding model or financial capabilities.

○ Value proposition – the value of cloud services vs. in-house services can be difficult to demonstrate when assessing service adoption

○ Integration of cloud resources with the local IT infrastructure can require much more effort than expected, delaying the time-to-production of the resources.

○ Contextualisation – Equipping the cloud resources with the needed software tools and configuration to tailor them to individual researcher needs.

4.2 European e-Infrastructure Projects

Supercomputing and cloud computing have been key ICT developments to emerge in the last ten years.

Based on the use of very large pools of computing resources, essentially processing, storage, and application software, cloud computing enables resources to be shared dynamically among multiple users. It benefits from the economies of scale achievable through very large data centres and enables individual users to gain access to large and variable amounts of computing resource without long-term investment. Obviously, this approach requires networking resources to access cloud resources, which will have an impact on network loading, depending on the nature of computing which may involve significant real-time interaction.

Supercomputers are expensive devices to build compared to cloud computing, which typically offers computer power that could be purchased by individuals for dedicated use. While some supercomputers may be dedicated to individual computational problems, they are also capable of being shared, serially, by different applications. In this case, network access to a supercomputer from a potentially broad user base becomes an important requirement.

Historically, networking was acquired as a stand-alone service to allow peer-to-peer communication between users. However, the development of e-Infrastructures, particularly in the areas of cloud and high-performance computing (HPC), mean that networks can now be used to access central ICT resources, and institutions view the acquisition of network service as part of a broader acquisition of ICT rather than as a separate, independent service.

Interactions between networking and other ICT services were also highlighted by NREN and project respondents, as Trust and Identity and Security for example apply across the range of ICT services. Since any service provider will wish to control and secure access to their own service, there is a risk that multiple developments by different ICT service providers will lead to confusion and may lead to incompatibilities.

Recognising developments in cloud computing and supercomputing, the European Commission has for many years sponsored a number of projects in the area, defined as 'e-Infrastructure'. The projects cover a range of technologies. The key projects are:

- **PRACE**, providing High Performance i.e. Super Computing resources [PRACE].
- **EUDAT**, providing distributed secure storage [EUDAT].
- **EGI**, providing Federated Cloud Services [EGI].

In addition to these three infrastructure projects there are related projects encouraging the use of e-Infrastructure, namely:

- **European Open Science Cloud**, to encourage the use of Cloud based services by scientists and researchers in Europe [EOSC].
- **OpenAIRE**, providing shared access to Research results [OpenAIRE].

GÉANT interacts closely with these projects, and Memoranda of Understanding (MoUs) exist between them and GÉANT. Greater efforts have recently been placed in this area to help realise opportunities for collaboration and synergies – to meet the current and future needs of researchers.

The interaction with this group is different from the interaction with International science projects, as it is both a customer/supplier interaction, e.g. PRACE uses a GÉANT MD-VPN solution and an interaction between service providers e.g. seeking to seamlessly combine services the various e-Infrastructures. Due to this multi-faceted relationship, it is important for GÉANT to understand the requirements of these projects as customers and co-service providers.

The requirements of e-infrastructure projects are covered in the Networking Activity 3 (NA3) Deliverable 3.3, which details the requirements captured over the course of several meetings and outlines what GÉANT can work towards to meet their requirements [D3.3]. The findings from the requirements gathering exercise fell into the categories of network, authentication and authorisation infrastructure (AAI), security, training, communications and marketing, and user engagement. The emphasis differed between the e-infrastructures according to their core activities. For example, PRACE had the most significant network requirement, including a new network topology. All the e-infrastructures (except RDA) have AAI requirements, with interoperability pilots planned for EGI and EUDAT; the AARC Engagement Group for InfrastructureS (AEGIS) is an important delivery channel for AAI recommendations and best practices.

For most of the e-infrastructures, the training requirement is to identify opportunities for cooperation and information sharing. Specific plans include GÉANT's leveraging of PRACE's massive open online courses (MOOCs) platform and deriving best practice from its successful summer school programme, exchanging training places with EGI, and developing joint training with EUDAT and OpenAIRE.

No specific individual marketing and communications requirements were identified. Rather, there is a general need to explore and develop collaborative marketing and communications opportunities.

Similarly, no specific individual user-engagement requirements were identified. Rather, there is a general need to explore and develop collaboration opportunities, and to share knowledge and best practice. Past and planned collaboration opportunities include joint organisation of "Design your own e-infrastructure" workshops, the Task Force on Research Engagement Development (TF-RED) and supporting the EOSCpilot project Science Demonstrators.

The e-infrastructures are also working together on the eInfraCentral project, and collaborative agreements are being produced between EOSC-Hub and GN4-2/GN4-3 and between GÉANT and OpenAIRE. GÉANT and PRACE are also planning a joint exascale workshop.

5 Conclusions and Recommendations

The aim of this deliverable was to collect a range of GÉANT stakeholder views about future developments to be pursued by the GÉANT project for NRENs and international projects, supporting their work during the next five years.

One **European NREN** stated that "no one size fits across all of Europe" and indeed, the interviews that were conducted did not converge around a single agreed picture. However, there was general agreement on areas that remain relevant for NRENs in the medium-term (Cloud, Security, T&I), as well as some specific ventures such as training programs, best-practice sharing, and service automation to save time and improve efficiency. Other themes related to service development, and it is recommended that the GÉANT business case process, whereby service development is sanctioned, continues to review experience (where appropriate), obtains a firm commitment of adoption and development, and takes a user-centric perspective.

International Partners were very positive towards GÉANT and seek to continue relationships in the future. Demonstrating value for money, extending the reach of T&I services, and a focus on security areas came through as pain points. To support and meet these needs, GÉANT could develop a training programme and incorporate International partners. It could also formalise cooperation regarding service provision to provide seamless service and support to those R&E partnerships.

International science projects looking across the five-year horizon saw the total cost of ownership for storage as their top concern and foresaw changes in compute models as a consequence. Some had an interest in direct interaction with the network. AAI was an area where there is a definite need – to bring together disparate locations – and save projects having to commit effort. Finally, cloud services continue to present many challenges.

It is recommended that GÉANT maintain close contact with this group of projects as a key input to the service development process. International projects are a good proxy for the wider GÉANT user base as, by definition, they require services in multiple countries. To gain a more precise perspective on project needs, GÉANT could consider other projects that are not actively addressed today, even though they may use GÉANT services. Equally important is the investigation and addressing of needs of pan-European projects that are not active users to determine whether GÉANT could meet these needs. Continued current effort in creating the Cloud IaaS Framework looks like a good way to address most of the concerns in this area, as is the case for the eduTEAMS service in relation with the T&I solutions. GÉANT can also take into account the shift in the use of remote storage (vs storage local to the site) when carrying out future network capacity assessment, since it could be an amplifying factor to the growth in network usage.

Within **international e-Infrastructure**, to meet ICT needs of NRENs and international science projects, GÉANT should continue to develop its relationship strategy, detailing co-operation with science projects, the supplier/customers relationship between GÉANT and other e-Infrastructures – and look for joint development work. In this way, the direct user constituency addressed in this deliverable will benefit from a clear service portfolio from across infrastructures that responds to their needs.

In isolation these findings cannot define everything GÉANT needs to do to meet the needs of GÉANT users (as defined here as those with direct engagement, such as NRENs and International science projects), however, this information helps increase understanding of the core challenges and contributes ideas to address them. The picture of the five-year horizon is constantly evolving. Continued engagement and dialogue to monitor these findings will determine GÉANT's understanding and preparedness to meet user expectations.

Appendix A Source Material from Respondents: Feedback and Future Requirements

Note the following feedback obtained to evaluate future requirements has been anonymised. Views expressed are those of individuals from GÉANT NRENs, Task Forces, Special Interest Groups and the Service and Technology Forum and do not represent the GÉANT Community as a whole.

A.1 NREN Feedback

NRENs were candid in their response to a number of interviews which concentrated on understanding their current plans and challenges. The highlights regarding what services and developments they want to see in the medium-term are presented here, with some duplication and diametrically opposed views. The aim is to provide an overall impression of the diverse issues and complex context of NRENs and their users.

General remarks have been loosely grouped into three areas: policy, communication/outreach and services.

A.1.1 Policy

- GÉANT has been built as a technical and political collaboration between NRENs. The human network is more important than just a network of PoPs, circuits and services (i.e. acting as a provider). Some of this collaboration has been lost, and more and more needed.
- Need to focus more on needs of the NRENs and their users
- Allow more time in General Assembly (GA) or other forums to discuss wider strategic issues for the community.
- Total Cost of Ownership changes (people, software) - need to discuss new architecture/industry ideas.
- Joint Research Activities (JRAs) are important as we don't have our own R&D activities.
- Deliverables are of excellent quality but way too long, should be limited to 80p maximum.
- Knowledge exchange across different platforms is considered valuable but it is important that concrete results are also being produced (such as IaaS Framework).
- Our vision is to start sharing data with other NRENs. GÉANT could promote cooperation and sharing of information and data act as a "trusted authority" (it means validate candidates for

data sharing -it must be kept tidy and is necessary to know who produces data and how such data arises).

- Want more transparency in cost share strategy.

- Would be interested in subsets of NRENs together with GÉANT (as coordinator) to be able to make proposals for projects outside the traditional areas of networking – more towards solving specific problems (e.g. those outlined above).

- Services not just for R&E community, but also for commercial – aim is to cover cost of service maintenance. Would like to see GÉANT move in this direction, as could create extra income source for all in GÉANT but recognises that GÉANT is built of NRENs with different models, meaning this is more complex for GÉANT.

A.1.2 Communication/Outreach

- TF/SIGs: See an importance of sharing experiences within platforms where NREN can share, discuss their problems, needs and solutions.; Legal aspects (GDPS, eIDAS, medical / personal / commercially sensitive data).

- Is there a plan in GÉANT to work on network function virtualisation (NFV) knowledge exchange?

- Demand for more collateral which can be used nationally. Some NRENs do not have own marketing staff.

- Sometimes students not aware of NREN or GÉANT. Some NRENs have no direct contact with researchers, as they primarily serve the IT centres; not aware of GÉANT product marketing activities.

- Would like to team with GÉANT for joint outreach e.g. joint booths/industry events or similar.

- Desire for greater support in service provision, e.g. presentations/session and adoption support at national conferences.

- Repeated request for a need of a project-wide CRM and join up with Compendium data and analytics to reduce number of surveys.

- Would like to see similar events such as the Earth Science Workshop carried out 2 years ago, organised by GÉANT with all other e-Infrastructures.

- Training still of interest (in networking and security etc).

- Lack of service promotion, no product marketing material.

- GÉANT important information source on developments in the industry and community.

- Greater need to coordinate international R&D communities and their needs (physics / energy, life science / bioinformatics, earth and observation, linguistics).

- Interested in more training for all aspects. Would be interested in someone from GÉANT to come for some specific hands-on training/assistance. Training has to be face-to-face, talking to all universities, giving in-depth, drill down information. Would also like more training events to be held in Europe.

- Use SIGs and TFs more: for dissemination and input to new ideas for project activities. Recognise more the human network within the GÉANT Collaboration - not just the operational network of PoPs etc.

- A Partner Portal that shows all the services we take, allows upgrades, provides service. information and so forth – basically what we have now refreshed/updated and working.

- GÉANT support with awareness building of services to end users (link to end sites/influence is limited).
- GÉANT support making NRENs more visible - especially important for small NRENs.
- Roadshow across country, organised by NREN/MAN inviting local universities. Promoting all the services.
- GÉANT has event-organising expertise. We should be able to offer to organise events beyond TNC.
- TF-RED is seen as a good development to help reach out to large user groups – with a view to helping to identify users in country so that the NREN can reach out and ensure that needs are met. It is essential that GÉANT maintains respect for NREN boundaries. The approach should always be to approach the NREN first.
- Would like to see marketing animations that can be customised for NRENs, and would like GÉANT to do more promotional material, e.g. l the eduroam video. There should be more emphasis on generic material that can be locally branded.
- GÉANT should keep the Compendium – very useful internally.
- In general (for all service types), if an NREN somewhere is doing something, would like information on this and if the service is to be made available more widely via GÉANT.
- More important are community activities and opportunities for knowledge exchanges (events, task forces, SIGS, workshops...). Key interest in learning from each other. Very important: Case for NRENs, value proposition -what NRENs bring to their users. Very interested in TF-RED to increase contact into research community; Community aspects are a lot more important to long-term sustainability then the project.

A.1.3   Services

- No "one size fits all" across Europe so we need to move from this to distinct services.
- GÉANT can play a central role in animating, helping the community to catalyse / help NREN to provide other services than network connectivity.
- More agile and timely delivery of required innovation from GÉANT projects (e.g. DDoS issues, RT Video, End User Network Services).
- Open Call activity was very successful and something similar would be much valued.
- Hot topics for users: security and privacy, lack of skills and resources, data increases, access to research friendly cloud resources.
- GÉANT is too focused on the network and not enough on other (above the net) services. We need a much better balance. Including (and especially!) security.
- The requirements of our customers define our needs for applications and software - if GÉANT is offering applications or software that is in sync with these requirements then we are open to adopt these.
- We strongly prefer applications or software available as white label, so an NREN can incorporate the offer in its own portfolio and a university can in turn apply their own label.
- Service lifecycle for research phase - manage and foster new ideas, including timescales.
- Would be happy to pass on services developed to other NRENs, but legal questions are unclear. Also, do not have the resources to provide support for implementation and support.

- Software development becomes more relevant, but main cost factor is code maintenance.

- Not much active involvement due to size of the NREN but like to be informed early on and understand what new trends are and how they can be adopted to stay up to speed. Not necessarily service developers or early adopter per se but select services which are expected most important and useful for most of their constituency (e.g. eduroam, eduGAIN, TCS, FileSender, now probably IaaS Framework).

- Better service/support for "huge file transfers" becoming more important (something like coordinated world-wide Science-DMZ infrastructure).

- Limited scope in expansion of own service portfolio –now own service development can only adapt–for this GÉANT is useful–preferably out-of-the-box services, which can be taken on.

- Service are being developed but nothing happens after that (e.g. MD-VPN, GTS). Business Cases unclear. All Business Cases should be finished before submitting the proposal to develop a new service!

- There is a need for data services for e.g. Life Sciences; Requirement for reliable file-transfer service provided on European (=GÉANT) level; some areas are looking for a content distribution network (CDN) for such data/databases, which has significantly different needs than traditional CDN used for commercial companies/video distribution (large datasets, access control). will need support for data services, which can be used with "medical data".

- GÉANT to do more to encourage service take-up – amplify what NRENs are doing (this is a change in culture) – avoid competition by saying who developing what (converge on what people do) - GÉANT should offer a list of what NRENs have available and NRENs choose.

- Mixed feelings on Inter-NREN offerings. NREN should not become competitors. Collaboration should be handled through project or as informal as possible

- Want to understand GÉANT service portfolio better

- Enhance services rather than more services.

- Work so far focused mainly on technology and this is working well – however, what is now needed is full production support to provide services that work with defined Service Levels and a support function. GÉANT should not only coordinate but also provide Service Assurance.

- Hesitant to look at broader adoption of GÉANT Services due to lack of sustainability. Due to project funding, high risk/uncertainty about future service development - will the service be further supported, to what extent, will it be further developed?

- In general, emphasis should be less on technology, more on how to solve the problem.

- GÉANT should help to ensure services provided are interoperable.

- Wish to work towards greater automation, end to end, for deployment of services. This should be not just for network management but also for applications of all types. Service would be ordered from a single location with all services available there (like a mobile operating system store). Technology-wise, the pilot within GN4-2 is the start of this (JRA4-T5). By 2018-20, would like to see a platform more widely available. Single-stop-shop.

A.1.4   Network and Network Services

A.1.4.1   *Network*

- The ideal GÉANT network is built on NRENs resources with cross-border fibre (CBF) interconnecting with multiple paths.
- Enabling collaboration between different countries (virtually).
- Find a sustainable model for CBF EC funding.
- Innovation (stay ahead of plain vanilla ISP)
- Closing digital divide (e.g. extremely expensive fibres in some countries) etc.
- The network will become a fully federated infrastructure that optimally integrates national network infrastructures by using alien waves and cross-border fibre, where possible, and only using commercial infrastructure where required.
- Would love to see three scenarios for the network moving forward:
  - A 'bare minimum' network that will just fulfil the expectations and uses all available resources from NRENs at minimum cost.
  - A good network scenario. The network that is clearly ahead of the vanilla ISP in terms of services (L2-channels etc.), bandwidth, redundancy, security and latency. A network that optimally services advanced research projects while at the same time serving less demanding uses for education etc. In other words, the network that we want.
  - An all-inclusive network. This includes all the network features that any NREN member wants. This is in all probability unaffordable, and therefore we need this scenario to show just that.
- Automation of all network services: orchestrating our own infrastructure (multi-layer: photonic network + switching + routing + NFV) to deliver all services fully automated to institutions via a dashboard interface or API. Institutions can setup all production services within minutes.
- Delivery of Virtual Network Functions (VNFs) to provide institutions a virtual appliance of any hardware device they nowadays possess (e.g. firewall, switch, router). This will allow institutions to minimise use of specialised hardware on-site and provide them flexibility to switch between different suppliers of the network functions quickly and easily.
- Move from fixed to wire-free networking.
- Expecting 400GE at the client side interface; experiments with 1Tbps.
- Start a clean slate approach by implement pure SDN technology and "a" is provided as a service instance of this SDN network.
- Go for a hybrid network implemented as a composition of current paradigm hardware and implement SDN for specific application and use case where SDN simplifies the set up compared to current network paradigm. Implement this by studying white label boxes. During discussion, it has been reported that GÉANT services are expensive. Leveraging white label boxes can be used in some part of the GÉANT network to reduce cost. Some NRENs are knowledgeable enough to build a router from scratch from these boxes, why not take advantages of NREN expertise to study this opportunity?
- Automation and network continuous integration and delivery (CI/CD) can have a positive impact and might change how the Network Architecture is modelled and enforced.

- Enforce CBF use. And where possible, deploy network segment between countries managed by GÉANT.
- Sharing of infrastructure: reluctant as existing infrastructure is required for national users; Pilot to understand technology and how it could best work (but not on production level); User demand requires us to keep spectrum for ourselves.
- GÉANT to do a pilot to define an interservice provider delivery framework. Need to work on stitching the vendor technologies together. Focus on interoperation. Don't have the interoperability skills - need GÉANT to get software integrators. Need to build the expertise. GÉANT should make this a priority for the next project.
- Against parallel fibre infrastructure of GÉANT and NRENs -this should be aligned -no parallel infrastructure! More unified use of equipment and consideration of nationally available infrastructure before developing new services. This of course, among NRENs and GÉANT, needs harmonisation of long-term strategies and concepts, defining joint standards and interfaces
- SDN: Interested in Orchestration and Automation of Services.
- At present there is a divide between those on the fibre cloud and those not, which needs to be examined. For instance, today some NRENs do not have access to the GÉANT Lambda service.
- Looking into SDN; white boxes. Would like GÉANT to have been more advanced in this area so NREN could benefit from GÉANT's experience. Interested in more info on what we are finding. (Not requesting SDN from GÉANT now.)
- Our community can't continue to operate networks in the same way we do now. Greater automation is needed. This will make it possible for a focus on other areas, such as projects and professional services. Help from GÉANT would be welcome.
- There is no lack felt in terms of having SDN and automation. We are not ready for it yet.
- CBF paperwork should be made easier.
- Much lower network costs.
- Each NREN should take responsibility for cross-border fibre (CBF) e.g. 1 x link into the country and the other 1 x NREN fibre. Ask NRENs "Where would you prefer to meet GÉANT?"
- Certificate Transparency (CT) log service to be run by GÉANT. Interest in running a global service.
- Do not view SDN as ready – only Google has deployed in production. So is not driven towards SDN as a principle, but only if technology provides for it, when they re-procure equipment.
- Wishes to see GÉANT providing the same service we provide today but reducing the cost of equipment – use new technologies white-label boxes with software more co-developed may be cheaper than other providers.
- SDN – take note of the advances – aim would be to procure a budget for equipment. Aim is to keep with typical optical and routing equipment – in short term do not see an SDN revolution domestically.

A.1.4.2 *Network Services*

- Efficient and not expensive IP at Tbps scale is the main required service.

- Connectivity services at Transmission level deployed using NRENs infrastructure, including CBFs.

- A shared solution for metrology would be ideal.

- NREN services have become a critical component in the primary processes of our institutions: this dependency warrants the need for predictability and hence the importance of service level agreements (SLAs) and key performance indicators (KPIs) are expected to increase.

- Open protocols and software are a must when the management of network devices relies on them: for automation and orchestration of the network we want to be able to replace certain technology layers –e.g. transition to another vendor –with minimal impact on the network orchestration/automation tooling. We support (open) standardisation where possible, we would expect the same from GÉANT.

- Fully Automated R&E SaaS/PaaS platform developed under the umbrella if GÉANT and instantiated within each NREN in a federated model.

- Testbed: No plans to establish testbed, as don't see a need; In 2014 carried out some 400G testing but one off use case.

- Wishlist for SDN project developed software: joining a pilot yes but reluctant to adapt for production network (sustainability and control).

- GTS should only be continued if there are actual users.

- Potentially improvement of end-to-end delivery, can operations procedure be more coordinated across NRENs, e.g. for mitigation.

- Set up Lambda Service specifically for short-term setups (quick provision and low price reflecting the short duration).

- A service which could provide NSI (Network Service Interface; a signalling protocol for an automated service provisioning) provisioned Ethernet circuits with guaranteed QoS in the per circuit manner.

- Interested in multidomain peering between GTS and own Testbed Facility.

- For video demos –we need ad-hoc setup of E2E circuits for real-time / multimedia transmission where the main criterion is jitter.

- More network services available in a "shared marketplace" where they can buy other NREN services in a turnkey way.

- End-to-end (E2E) services of interest to Jisc but don't feel business model there – we need to build a commercial model for it (service agreements, hiding of cost difference, etc.)

- Out of hours support.

- No testbeds for the sake of it – project specific – maybe quantum space.

- Some services that GÉANT has developed have not been suitable for us, e.g. BoD, which required deployment on backbone.

A.1.5   Security

- Shared Scrubbing Centre for NRENs (services).

- Not 'just' filter-based/Firewall-on-Demand type services (although that could use a boost).

- Specialised hardware (e.g. Arbor TMS) is expensive, but under-utilised when procured by NRENs individually but we can't do without (if we would like to keep our network really, really clean and pristine).

- 'In the cloud' solutions usually mean re-routing all (or large blocks) of traffic ￫privacy/security issues.

- Connectedness of NRENs makes it feasible to develop own setup and procure scrubbers without these drawbacks.

- More 'bang for your buck'– can afford bigger scrubber when resources pooled/shared.

- Computer Emergency Response Team (ERT/CSIRT): Operational CERT required with (growing number and scaling of) services; Good operational contacts with NREN-CERTs; Information exchange; Training/exercises?

- Security Operations Centre (SOC) services: Development of services as offered by SOCs (which may differ depending on SOC-type: operational, monitoring, controlling)

- (Further) development & sharing of threat intelligence (services): Aggregating Open Source intelligence > demo available; possibly threat intel from large scale DNS monitoring?

- Cyber threat assessments.

- Risk register (management/strategic).

- Services in general that improve security and/or privacy (services): eduVPN is a good example of this (user-friendly open-source solutions to privacy and security issues); Pooling development, knowledge, cost, and infrastructure makes business sense.

- Cyber crisis exercises (OZON) (awareness/communities).

- Cyber Save Yourself (CSY), cyber security awareness campaign material (awareness)

- Security & Privacy standards & frameworks (also relating to GDPR) (standards)

- Business continuity & crisis management

- Security functions are expensive. Security at higher scale is unaffordable for academics. NFV and SFC can be used to provide traffic scrubbing centre, filtering for NRENs especially NRENs who can't afford this type of service but also global customer like EU agencies connected to GÉANT network.

- Blueprints and standard solutions for challenges that are similar among research bodies (fitting Audit-schemes for research bodies, pragmatic baseline information security processes and corresponding technical solutions).

- DoS-protection between networks –some NRENs have a powerful DoS-Mitigation platform, but if attacks overflow our peerings/upstreams, we need to mitigate outside our own network. We need organisational and technical solutions to be able to react to such attacks instantly. Today, these processes and technical solutions do not yet achieve this.

- Security co-ordination needs to improve.

- Security: OSS/BSS specs being done - same approach for data scrubbing and VM protection solution. A reference implementation which NRENs could re-use would be very useful. 1.Identifying attacks 2. Mitigating and defending attacks (it's important to proceed with Flowspec solution in a more integrated manner). Flowspec rules should be shared. This should be the number one priority. GÉANT should propagate the relevant NREN rules.

- A service like Firewall on Demand (FoD) is considered very useful.

- Would like to see NetFlow and SNMP data from links between GÉANT and an NREN.

- Reputational shield: designing own reputational shield already with international partners, also work on scrubbing service. GÉANT could re-use this information for a pan-European Service Offering.
- Penetration Testing Service on pan -European level: offers it nationally but would like to provide a service to their users beyond national borders. Is this something which could be picked up from GÉANT?
- Very interested in any new DDoS services e.g. DDoS washing machine.
- Certificate service covering Europe and US.
- GÉANT DDoS prevention and mitigation – a temporary shelter for services under attack.
- Security "standards" on a European level could make the situation at the NRENs' level much simpler and easier. Uniformly agreed and accepted principles and practice on security are very much needed.
- Currently the Security activity around GÉANT has lost its focus.
- Greater automation of security mitigation. Security requirement volumetric attacks. Greatest need is efficient and automated services that provision assistance without NOC operators.
- Demand for granular security measures on network side (DDoS reporting).
- GÉANT Clearing House: Commercials offer Big Clearing centres - for single NRENs not worth to offer but see huge benefits as joint offering.

A.1.6   T&I

- Clear business development process –pragmatic, based on the needs of NRENs; explicit attention in the project for the handover phase (innovation-operations); develop standardised functional building blocks, which can be used in different ways; highly-skilled people (product management, technical), infrastructure, expertise on high availability and software development.
- What we need: eduGAIN services and support should be structural and not only depend on EU grants; further support and coordinate international collaboration for research; Represent the community when it comes to standardisation
- GÉANT must be an organization that can facilitate proper operation of services (above the network). This should be done in close consultation and / or cooperation with the NRENs.
- Provides support for level of assurance (LoA)-related affairs (technical, policies, knowledge base, ...), i.e. expand the respective activities in JRA3, T2.
- Set up and operate an OIDC federation testbed installation (→ JRA3, T3).
- Knowledge base + competence centre for T&I-related (+ data protection) topics.
- Proof-of-Concept (PoC) installations for upcoming technologies and concepts.
- Community engagement.
- Have to enrich the services rather than plain eduroam access. Need enriched eduGAIN. AARC project - X509 certificates are needed. Want the GÉANT project to bring new products forward. Raise profile of AAI - and need to be more active.
- Interested in govroam.
- Turn-key solutions.

- Operations support is lacking, a technical single point of contact (SPOC) is needed; Incident reporting.

- Full integration of all ESRI project and e-Infrastructure sites in eduGAIN should be pursued. Research is international today in all areas and federated access to resources is a key requirement.

- Digital identities and group management tools reflecting the project based working environment of researchers.

- Easy inter-federation / engaging commercial partners in eduGAIN (several research infrastructures will be providing services also to Commercial partners –where trust and security is a must).

- Inter-federation of other ESFRI nodes where NRENs are a member (i.e. linguistics, social survey groups are not in eduGAIN in some countries).

- Users' accounts and data provisioning and deprovisioning; group memberships and roles sharing across infrastructures and services; identity consolidation and linking (one user account multiple digital identities); eID systems integration; deploy and provide systems (e.g. Perun) which can take care of above topics for research infrastructures/communities.

- Would like to see common T&I templates across Europe to ensure federation compliance.

- GÉANT to take on some kind of role in the Shibboleth consortium.

- Ask that GÉANT leads with plans and vision – like TIC doc (which is still valid but needs 'operationalising').

- eduGAIN needs more policy – revisit governance before revisit policy.

- Integration of publications' databases with eduGAIN so that users can access the data based on their credentials. It would also imply much finer granularity and tracking capabilities for the service providers.

- Would very much welcome hand on help to set up IdP and eduGAIN.

- GÉANT has a key role in T&I offerings, NRENs themselves can't solve one AAI problem of the HEP or Lifescience community because they all work internationally.

- Key challenge is operation of T&I services - how are they supported? Network Services have a well running system with Service Manager, Product managers and an Operations Centre - T&I is lacking this.

- Wants T&I in multi-domain environments to always work- collaboration of different systems, SLA. Things to improve performance, faster, more secure.

- Does not have the size to innovate on its own, but also thinks it is beneficial to work with GÉANT and the resources available in the project, including with other NRENs.

- Multi-factor identification will become an issue for research sites, etc. There needs to be a focus on AAI best practices.

A.1.7   Cloud and Framework Agreements

- Users become customer and provider of Cloud services at the same time.

- Customers want storage. This is the "hottest" topic. Legal and technical issues of cloud.

- Videoconference (VC) service procurement - deeply involved, very relevant - don't have solution other than Adobe and not satisfactory.

- Joint Framework Agreements considered as very valuable and should be expanded in the future – negotiate better T&C for the national service offering of NRENs.
- Current procurement activities not useful for us, achieved prices not interesting in our country as personal cost is still significantly lower here, therefore local price is usually lower too, don't expect significant interest from our organisations; IaaS from commercial companies may be used just for intermittent, temporary needs -no significant numbers can be expected here.
- SaaS services are not significant due to nearly cost-free offers from some vendors for certain services; is missing support actions for NRENs, which provide compute/storage cloud services on their hardware/premises.
- Would like to have a platform to exchange technical issues (implementation, hybrid, scaling, eduGAIN integration) related to cloud offerings. The Cloud Team so far only covers the commercial aspects of the service offering.; A Task Force for Cloud Adoption might also be beneficial.; Don't see potential in building own GÉANT cloud service. GÉANT should rather remain in its role as broker.
- Would like to see Distributed TURN infrastructure (operated within NREN, managed under umbrella of GÉANT) –media relay, relay over NAT; WebRTC –will still be operated by NRENs, from GÉANT sharing experiences.
- The entire tender process for cloud services was made needlessly complex and so it isn't possible to compare like for like. There is a website where prices of services around the world can be compared. The GÉANT process put a lot of effort into analysis of the offer, and the results are not clear.
- Cloud usage monitoring could work at European level.
- Joint Procurements are becoming increasingly important. For now, mostly Framework Agreement but in the future also look into reselling services.
- Would like to see a working group of legal advisors to advise on national legal issues relating to IaaS and cloud service issues, e.g. if an NREN has run its own procurement, can it then still use the GÉANT framework. Legal advisors maybe need to meet to work this out.

A.2 Task Forces, Special Interest Groups and Service and Technology Forum (STF) Feedback

The following represents a brainstorming wish list of future investigations/developments, as gleaned from presentations and discussions within SIGs and TFs.

A.2.1 Managing Service Portfolios and Marcomms

- Cost reductions and/or enabling an NREN to make money serving the community.
- GÉANT backbone based solely on NREN connections + cross border fibres.
- Network wide Distributed Denial of Service (DDoS) mitigation service.
- More joint procurement activities.

- Greater emphasis on NREN-to-NREN service provisioning.
- Orchestration of point-to-point connections through open application programming interfaces (APIs).
- Enable eduGAIN to support ad hoc federations.
- White-label services (NREN able to rebrand as their own) and white label applications or software so can incorporate into NREN own portfolio
- Services can be sourced from anywhere, as long as they have end user appeal and are affordable; open protocols and software are a must
- Need for more services focused on campus domain, ICT services, etc. GÉANT to help improve national service delivery and economies of scale.
- Current GÉANT portfolio reflects tech-driven services. Some NRENs started to facilitate coalitions of the wiling (ICT managers, etc.) to help develop and launch new services, resulting in portfolio extension. Call for demand aggregation, joint tendering, and tender management as something GÉANT can help to support.
- Staff needed to facilitate largescale procurement, operation management in trust, security & cloud. GÉANT leans on NRENs for running T&I and security services, would be good if GÉANT staff could do that. Support also needed for the ICT management of organisations such as NATO, ESA, UN that need GÉANT and NREN resources.
- GÉANT Academy to help NRENs acquire skillsets.
- Automation of network services.
- Entering campus domain with service that allows us to manage their WIFI; would be good to use a control plane to include campus domains.
- Clouds – many campuses want to get rid of ICT depts. Also, to use commercial solutions via NREN as broker of commercial services in response to customer requests.
- Standardisation where possible.
- GÉANT could support NRENs moving in direction of offering scale advantages in demand aggregation, joint tendering and vendor management. For example, recent IaaS tender: we use the results as building blocks for our cloud service.
- Procurement is increasingly complex, requiring an extensive mix of legal, procurement and technical skill sets: institutions may look at NRENs to coordinate these procurements and NRENs should seek collaborating with other NRENs within (and serviced by) GÉANT.
- Offer an integrated mix of: university-offered cloud services, NREN-offered cloud services and commercially offered cloud services. This requires central procurement to achieve economy of scale.
- Current IaaS tender was a very good step in right direction. Requires product management at GÉANT that consider how to work with the different NRENs that are at different stages of dealing with this.

A.2.2   Greenhouse

- Developer community waning within the NREN world.

- Lots of reliance on OSS but no strategy for long-term support for the software, very few NRENS have development strategy in place alongside procurement strategy, difficulties with maintaining developers.
- Work on Docker recipes and approaches.

A.2.3   Multimedia

- Open Educational Content: make them accessible and re-usable.
- In-context based real-time communications. Application development based on the WebRTC protocol. Real time traffic (audio, video, data).
- Make the GÉANT TURN Service pilot global (nodes in Americas, Asia Pacific, Africa).

A.2.4   Information Security Measurement (ISM)/WISE

- New service / development requirements =
  - Information security measurement (ISO27004:2016)
  - 5G development vs. WiFi and eduroam

A.2.5   Next Generation Network

- NFV and Service Function Chaining (e.g. Contrail).
- Consider how realistic (viable) is to develop services in SFC space in the NREN community?
- Network Automation and DevOps.
- Practical SDN.
- IoT.

A.2.6   Network Operations Centre (NOC)

- There is a trend towards 24/7 support.
- With the increase of international cooperation and exchange, clients have users from different time-zones and different countries, so they expect their students and employees to be able to have access to the network from any place, at any time.
- There will be a need for more managed services : Radius; Authentication services; Federated sign on; Things that have been installed at one point in time and if they break, there is no one to fix them, especially in this age of automation.
- Offering assessment to an NREN and its connected entities:
  - With so many different services, clouds, complicated laws... The network is seen as a commodity but the situation is more complex than that. Large universities or entities usually have good teams and technicians, but small institutions can't afford to have many people and they need assessment. This assessment could be in many fields, like: Deciding what services should go to the cloud and what services don't needs cloud transformation; General Data Protection Regulation compliance; network configuration; network

monitoring (such as Network Monitoring as a Service (NMaaS); teaching support innovation; virtual Campus creation, development and deployment; Big data. Perhaps GÉANT could offer this assessment, maybe each NREN could specialise in one or several items.

- Innovation for e-learning, teaching services to foster online teaching, master classes, e-portfolios.

- Applications control everything, but automation and orchestration are essential to keep these applications running and to have all our network and systems equipment (logical and physical) items under control. Monitoring is always healthy, as a key for fast resolution of incidents and to anticipate future issues. Not only for the network.

- New services or new service features be developed only after a certain minimal number of NRENs express their commitment to offer/use them for their business

A.2.7   Computer Security Incident Response Teams (CSIRT)

- Increase amount of time allocated to TF-CSIRT given its size and ambition of the new TF-CSIRT Strategy.

A.2.8   Cloudy Interoperable Software Stacks (CISS)

- Transnational compute-job mobility in the form of docker containers that can be moved at will between different NREN cloud stacks, supervised probably by some sort of meta-orchestrator, and ideally with the collection of pre-packaged workflow containers available in an "NREN science app store".

- Federation of data storage with ability to run computations close to the data.

A.2.9   Mobility and Network Middleware (MNM)/other mobility groups

- Internet of Things: LoRaWAN infrastructure (or others in the licensed/unlicensed spectrum band, e.g. 802.11ah/NB-IoT).

- LTE-U.

- Internet of Things: "Smart Campus".

- Indoor Location Based Services.

- Fixed/Mobile integration on campuses, helping institutes purchasing the right "mobile service".

- Supporting/pushing WiFi-calling at the campus.

- DAS-networks: still needed, or obsolete?

- Robust and redundant unwired network deployments (at campus) for emergency situations.

- 5G projects and developments.

- Wireless service (and beyond?!) by NRENs: do's and don'ts.

- Cooperating with initiative such as WIFI4EU (or FON, iPASS, Boingo...).

- Developments and next steps for govroam internationally.

A.2.10   Science and Technology Forum (STF)

A.2.10.1 *Large-size NREN group*

- Intra-NREN service brokerage.
- Connecting EU agencies.
- Agility and cost for cloud services.
- Alien Wavelengths (AW) as a service.
- DDOS mitigation is expensive – need to do this effectively.
- If we use more Science DMZ then what does this do to security?

A.2.10.2 *Medium-size NREN group*

- SDN in the core – more testing needed before full implementation.
- White boxes
- Increase in user base – further expanding the networks.
- More automation of workflows.
- IPv6.
- Firewall on demand is a great service BUT we want faster deployment.
- Offer security services for schools.
- Importance of security is growing for government and all new users.
- Invest more in devices, software to mitigate security incidents. More automation of DDoS attacks – more details.
- Tools for processing the logs coming from the network.
- Large sets of processing monitoring data – process somewhere in the cloud?
- perfSONAR – not yet integrated everywhere in the day-to-day routine.
- Increased traffic for peerings. Should do more in GÉANT.
- Local cloud service development.
- The user wants "everything as a service".
- More services so the operation centres need to have the skills sets re: the new services
- New services that GÉANT could offer: firewall on demand, better response time and development time (it took 3 years for FoD) – advanced security services for traffic growth. Better support to MD-VPN.
- Need to automate network services. Still need to email each other, which needs to stop.
- General comment – speak with NRENs more frequently.

A.2.10.3 *Small NREN Group*

- Increase in user base from schools.
- VLAN splicing into the cloud.
- DDoS washing machine service. Should be developed ASAP. Must be quality BUT cheaper than what's available on the market.

- Leverage economies of scale to buy more off the shelf for smaller NRENs.
- Intra NREN service selling will be important.
- More and cheaper cloud services. Must be at least 20-30% cheaper.
- SLAs/SLT aren't an issue for smaller NRENs. Best efforts is enough.

A.2.10.4 *General Comments*

- Permanent firewall in the cloud (i.e. like FoD, but bigger and more persistent).
- Ability to automate provisioning of new services from GÉANT (such as setting up MDVPN, Firewall, new lambdas, etc).
- Speeding up the process of idea to execution, i.e. FoD took c. two years to implement from successful PoC, MDVPN similar.
- More of these kind of feedback sessions (more than once every 5 years).

Appendix B List of GÉANT Partner NREN Interview Dates

Number	NREN	Meeting Type	Meeting Date
1	DFN	Face to Face	04/04/2017
2	RENATER	Face to Face	22/03/2017
3	Jisc	Face to Face	05/05/2017
4	GARR	Face to Face	01/03/2017
5	NORDUNET	Face to Face	07/03/2017
6	RedIRIS	Face to Face	05/04/2017
7	SURFNET	Face to Face	20/04/2017
8	SWITCH	Face to Face	03/04/2017
9	BELNET	VC	26/04/2017
10	PSNC	Face to Face	10/03/2017
11	ACOnet	VC	09/02/2017
12	GRNet	VC	28/03/2017
13	IUCC	VC	24/04/2017
14	FCT	Face to Face	06/04/2017
15	CESNET	Face to Face	06/04/2017
16	HEANET	Face to Face	14/03/2017
17	RoEduNet	VC	30/03/2017
18	KIFU	written contribution	via mail
19	CARNET	VC	Apr-17
20	AMRES	VC	11/04/2017

21	LITNET	VC	Initial discussion 03/03/2017 Follow VC 03/04/2017
22	RESTENA	VC	10/04/2017
23	TMES/Latvia	VC	10/04/2017
24	CYNET	Face to Face	02/03/2017
25	MARnet	VC	31/03/2017
26	UoM		Took part in STF meeting (no bilateral)
27	MREN	VC	24/03/2017
28	ANAS	F2F	28/03/2017
29	RENAM	F2F	28/03/2017
30	ASNET-AM	F2F	30/03/2017
31	GRENA	written contribution	via mail
32	URAN	written contribution	via mail

Appendix C GÉANT Community Programme (GCC)

The GÉANT Community Programme was established in early 2016 to both replace and extend the functionality of the TERENA Technical Programme under Terms of Reference agreed by the General Assembly (GA(15)046).

The aim of the programme is to foster collaboration and support community driven initiatives in a broad range of areas, including innovation, management and operation, for the NRENs and GÉANT, to build communities, share ideas and solve common issues.

The three priority areas for GÉANT and NRENs as outlined by the GCC in 2017/18 are:

- Addressing the innovation pipeline.
- Supporting how NRENs comply with the General Data Protection Regulation (GDPR).
- Supporting the attribute release problem.

C.1 GCC Report: Radar Exercise

At its February 2017 meeting, the GCC carried out a Radar exercise. This encourages a group to look at the range of activities being carried out within its portfolio and evaluate whether activities should be STOPPED, PILOTED, TRIALLED or DEPLOYED by member organisations.

The GCC looked at categories within four areas: NETWORK, SERVICES, PEOPLE and OUTREACH and mapped these onto the radar. Due to the focus of the group, elements within the SERVICES and PEOPLE segments were selected.

The main areas identified by the group as relevant for development or review through the radar exercise are as follows:

- GÉANT to provide more advice and guidance on GDPR, via seminars and online material.
- Explore opportunities for a tender for multi-factor authentication (MFA) solutions or to rollout support for existing MFA tools within the community.
- Re-evaluate the GÉANT offer around Distributed Denial of Service (DDoS) Mitigation and pressing needs within the community.
- Establish a GÉANT e-learning strategy.

- Carry out a strategic review of dependencies and support for Open Source Software within the community, and the role of an NREN as software developer.

- Review community use of group management software and implementation.

- Review "federation as a service" and "managed identity provider (IdP)" offers and implement a service that better meets requirements of both fully managed federations and IdP offers (more akin to the Internet2 TIER offer).

- Addressing the gaps in the innovation pipeline between ideas developed in task forces (TFs) and special interest groups (SIGs) and the higher level TRLs in the GN4 project. This may involve looking at new funding models, such as Kickstarter-like fundraising approaches.

- Ask for more NREN support to develop mature IdPs capable of supporting the requirements of more complex use cases to solve the attribute release problem and help NRENS meet the GDPR requirements via mechanisms such as REFEDS research and scholarship (R&S) and the GÉANT Code of Conduct.

- Review requirements for the next-stage trusted certificate service (TCS), including impact of Let's Encrypt and ACME Protocol support on the market.

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Glossary

AAI	Authentication and Authorisation Infrastructure
CBF	Cross-Border Fibre
DCI	Data Centre Interconnect
DDoS	Distributed Denial of Service
DEC	European Commission
EGI	European Grid Infrastructure
EOSC	European Open Science Cloud
ESA	European Space Agency
EMBL-EBI	European Bioinformatics Institute
eVLBI	European Consortium for Very Long Baseline Interferometry
FoD	Firewall on Demand
GDPR	General Data Protection Regulation
GN4-2	The GN4 Phase 2 (GN4-2) project
GTS	GÉANT Testbeds Service
HEP	High Energy and Particle Physics
HPC	High Performance Computing
IaaS	Infrastructure as a Service
ICT	Information Communications Technology
IdP	Identity Provider
IPCC	Intergovernmental Panel on Climate Change
ISO/IEC	International Organisation for Standardisation/International Electrotechnical Commission
LHC	Large Hadron Collider
MD-VPN	Multi-Domain Virtual Private Network
MOOCS	Massive Open Online Course
MoU	Memorandum of Understanding
NA	Networking Activity
NREN	National Research and Education Network
OCP	Open Compute Project
R&D	Research and Development
R&E	Research and Education
SA	Service Activity
SDN	Software Defined Networking
SIG	Special Interest Group
SKA	Square Kilometre Array
SPOC	Single Point of Contact
STF	Service and Technology Forum
T&I	Trust and Identity
TESTA	Trans-European Services for Telematics between Administrations
TF	Task Force
TF-RED	Task Force on Research Engagement Development
TIP	Telecom Infra Project