ASPIRE

A STUDY ON THE PROSPECTS OF THE INTERNET FOR RESEARCH AND EDUCATION 2014-2020

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GÉANT

ASPIRE

"A Study on the Prospects of the Internet for Research and Education 2014 - 2020"

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Contents

1. EXECUTIVE SUMMARY

A Study on the Prospects of the Internet for Research and Education (ASPIRE) has been an eighteen-month Foresight Study exploring how Research and Education (R&E) networking could develop during the period of the European Commission Horizon 2020 programme[i].

Four in-depth studies by expert panels were undertaken into topics likely to have a significant impact on the future of R&E networking in Europe:

- the adoption of cloud services;
- the adoption of mobile services;
- middleware and managing data and knowledge in a data-rich world;
- the future roles of National Research and Education Networks (NRENs).

The findings of these groups are detailed in four online reports and summarised in Chapter 5.

In order to put the development of R&E into the wider context of technological developments in e-Infrastructure, and Europe's position in the digital future, a number of the reports and studies of other groups have been consulted. These are summarised in Chapter 7.

The threads from this work are drawn together in Chapter 8.

Briefly, we believe that aspiring to the future means:

- capitalising on the great success of GÉANT and the NRENs;
- collaborating and partnering with commercial players to jointly deliver the services required by the users;
- expanding the use of dark-fibre networks to support the flexibility and agility needed to support all users;
- leading the way on identity federation policy and systems;
- preparing for integrated mass mobile connectivity;
- expanding the community to include other publicly funded users;
- leveraging the knowledge within R&E networking for the greater good;
- implementing the recommendations of the Reykjavik Group;
- following the recommendations of the four ASPIRE topic reports, as summarised in Chapter 5.

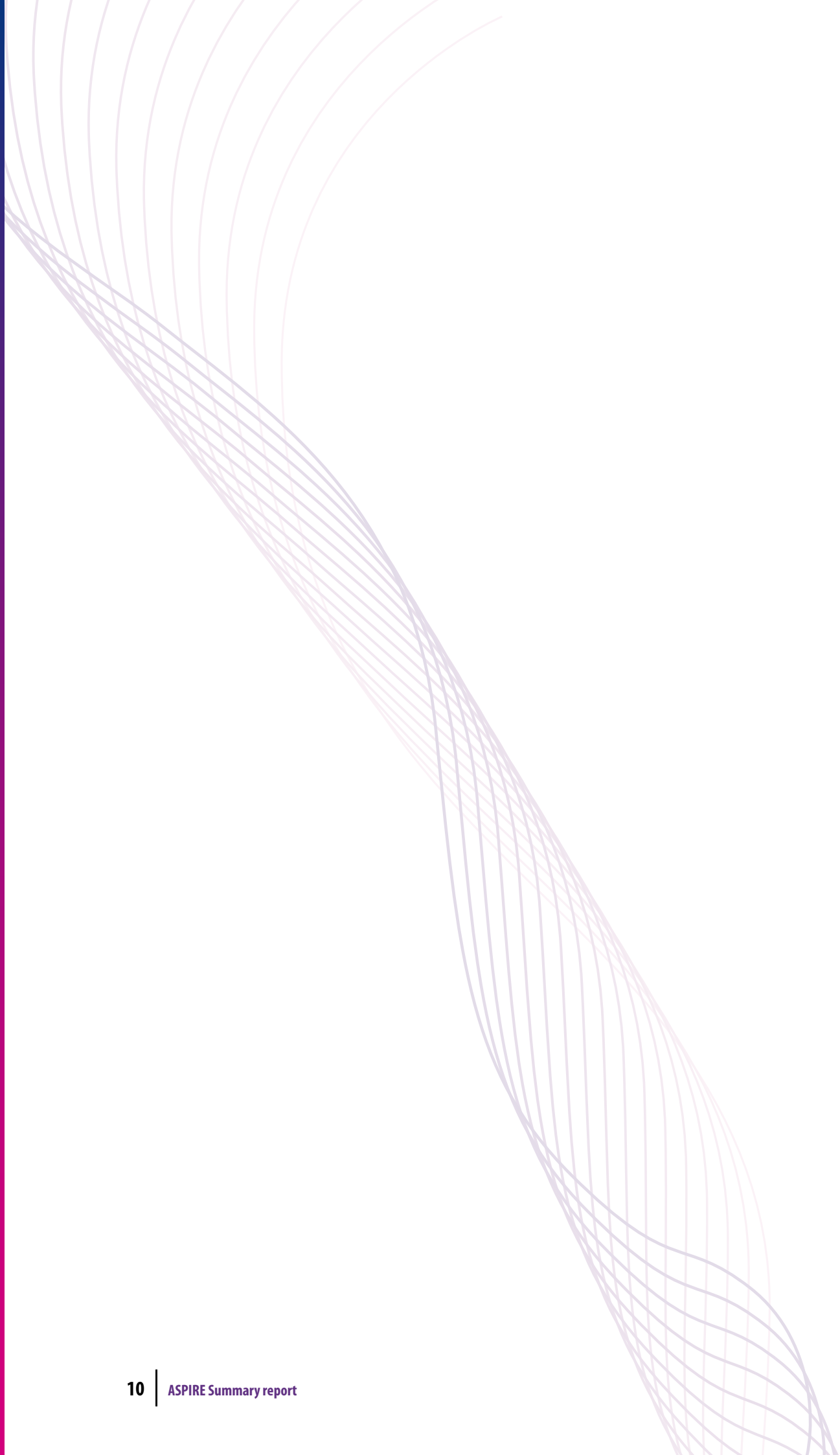
The remaining chapters of this report explain the background to the study, describe the methodology of the study, and summarise the proceedings and findings of the two key workshops.

The ASPIRE study team wishes to express its sincere thanks and appreciation for the work undertaken by the panel members and leaders and all others who have contributed to the work through participation in the workshops and in other ways.

John Dyer Magda Haver Michael Nowlan

December 2012

back to contents page



back to contents page

2. BACKGROUND

The ASPIRE Foresight Study is a task undertaken as part of the Status and Trends Networking Activity of the GN3 Project.

The ASPIRE Foresight Study prepares the ground for planning the development path of research and education networking infrastructure and services after the completion of the GN3 Project, at the local, national, European, and intercontinental levels. It is intended to inform the definition of Horizon 2020 (2014–2020).

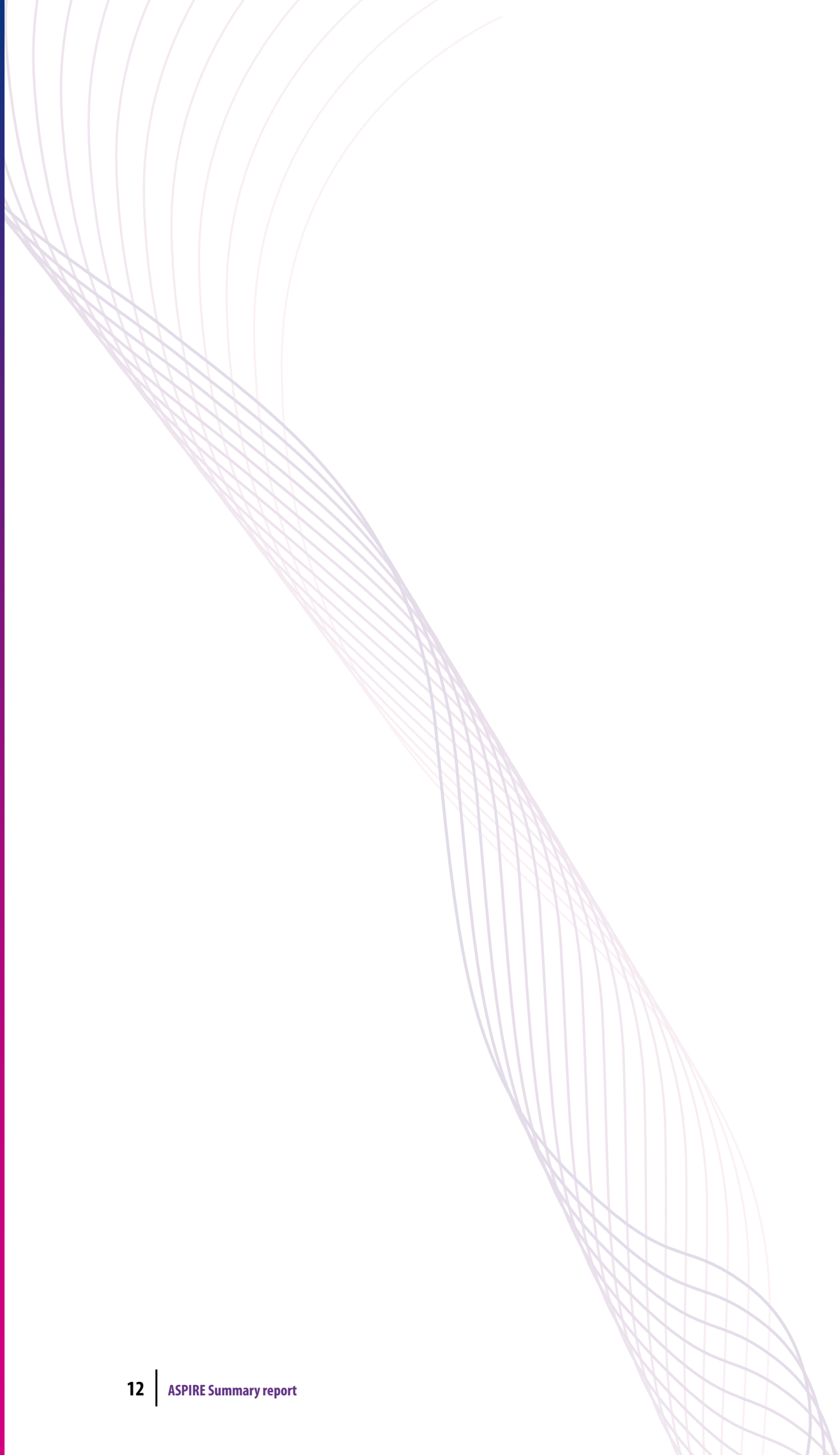
The objectives are largely the same as those of the large-scale foresight studies that were conducted in the Study into European Research and Education Networking as Targeted by eEurope (SERENATE) (2002–2003) and, as part of the GN2 Project, in the Education and Research Networking Evolution Study (EARNEST) (2006–2008).

Both SERENATE and EARNEST covered a wide range of aspects of research and education networking. In the period 2004–2005, there was a major paradigm shift in research and education networking in Europe. Nevertheless, EARNEST found significant changes in only some of the aspects under study, regarding the actual situation and future expectations, compared to those found by SERENATE.

Since the authors of the EARNEST Study did not expect a major paradigm shift in the 2008–2011 timeframe, the ASPIRE Foresight Study was conceived as an update to the previous work and its remit was limited to the investigation of no more than four topics.

The ASPIRE Foresight Study provides policy input for initiatives that can help keep European research networking at the forefront of worldwide developments, and enhance the competitiveness of the European Research Area.

back to contents page



back to contents page

3. METHODOLOGY

Members of the ASPIRE study team began work on the project in April 2011. An email distribution list was set up and a consultative workshop, aimed at the R&E networking community was scheduled for the end of May 2011.

During the weeks before the workshop, a list of potential study topics was developed in consultation with the members of the distribution list and others. The purpose of the workshop was to present and explore each of these topics in order to reach a consensus on which would be likely to have a significant impact on the European R&E community in the period up until 2020. In order to inject "new blood" into the proceedings, a competition was launched, in which students could propose their ideas on the future. The best four were invited to present their ideas to the workshop, which was attended by more than 60 participants.

The outcome of the consultation workshop was the choice of the four topics to be studied during the ASPIRE Project:

- adoption of cloud services;
- adoption of mobile services;
- middleware and managing data and knowledge in a data-rich world;
- future roles of NRENs.

The other candidate topics, for which there was no remit or resource for ASPIRE to explore, were:

- security / privacy / trust / legal issues;
- adoption and use of social media in the R&E community;
- non-commodity IP services as a substrate for science;
- architectures, technologies and organisational approaches for future R&E networking;
- content and access;
- solving the digital divide.

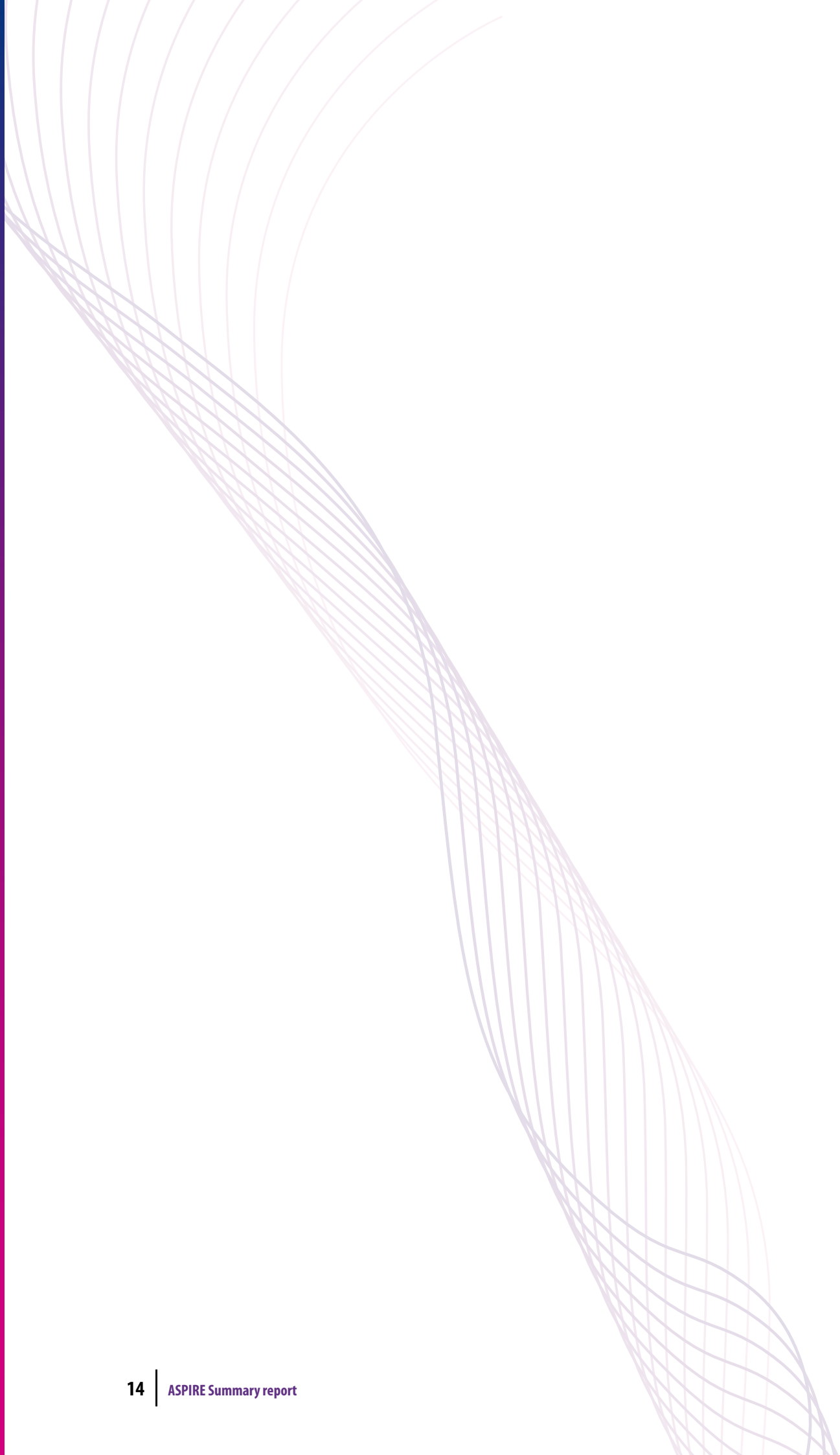
Following the selection of topics, four panel leaders and panels of experts were selected to work on the topics, and were briefed to consider:

- the current situation in the topic area;
- likely future developments in the topic area;
- the implications for the R&E community;
- conclusions and recommendations.

The panels met in person and by videoconference, and used collaborative tools such as wiki, online questionnaires, and interviews to gather information. Over the summer of 2012, the material was used to develop four topic reports. The reports were published on the ASPIRE web pages[ii] on 2 September 2012.

On 13 September, a stakeholder workshop was held to engage members of the European R&E community in assessing the findings of and recommendations for the four topics. Discussions at the workshop were open and far ranging.

back to contents page



back to contents page

4. INITIAL CONSULTATION WORKSHOP, MAY 2011

Overview

The ASPIRE study team held a consultative workshop for members of the community on 23–24 May 2011 in Berlin, Germany. The goal of the workshop was to provide guidance on identifying the most important future developments in R&E networking that should be explored in depth by the ASPIRE topic studies that were due to start late in 2011.

More than 60 participants attended the workshop, representing a wide cross-section of countries, institutions, and areas of expertise.

Day 1

On Day 1, John Dyer, the ASPIRE Project Manager, provided an introduction, explaining the context of the study and what was expected to be achieved during the event. This was followed by a presentation by Karel Vietsch, who summarised the findings of the two previous TERENA foresight studies: SERENATE (2002–2003)[iii] and EARNEST (2006–2008)[iv].

back to contents page

A number of invited experts provided some personal views to stimulate thought and discussion. The presentations included position papers on the following topics[v]:

- security / privacy / trust / legal issues;
- dynamically provisioned networks as a substrate for science;
- cloud services;
- adoption and use of social media in the R&E community;
- lif/ve of the network – living off the network (utilisation) and life of the network (evolution);
- arks for the data deluge – how to survive the rising tide of data.

After hearing the presentations, delegates were divided into six breakout groups to review what they had heard and add their own ideas. The output from these groups was later presented in a plenary session.

Following a competition, four students had been invited to the workshop to give their ideas for development of the Internet for R&E. The rationale for inviting students was that they would likely be unfettered by traditional thinking. Their presentations were as follows:

- "Mobile Computing and Mobility in Education" addressed the use of mobile-augmented reality for instant access to additional information about particular objects in one's surroundings;
- "Creating Networks Using VLAN and VRF" explored the use and advantages of virtualisation for study purposes;
- "IPv6, Mobility and Opportunistic Encryption" included ideas on how to bring about more secure, reliable, and transparent roaming between wireless technologies such as WiMAX, Wi-Fi and 3G;
- "A Next-generation Social Network Built around European Institutions" explored the use of social media to underpin a cohesive and mobile environment for students and researchers.

Day 2

On the second day of the workshop, the material that had been presented was discussed in plenary. The objective was to guide the choice of topics that were suitable for ASPIRE to explore in depth. These discussions were unstructured, far ranging and contained many insightful comments and ideas. Following discussions, it was agreed that, of the topics presented at the workshop, the four areas selected for study would be cloud services, mobile services, data deluge and the future of NRENs. The following sections summarise the discussions by topic.

Cloud Services

The use of cloud services is an attractive proposition for many institutions. Commercial cloud providers offer a range of on-demand and exceptionally scalable services including compute power, data storage, applications (mail, collaboration tools) and access to specialist software (for example, Customer Relations Management (CRM)).

The pricing models of some commercial cloud providers allow the concurrent usage of 1,000 processors for one hour at a cost similar to the usage of one processor for 1,000 hours. This enables end users to compute results from their data in a fraction of the time it took using traditional approaches of owned hardware. The instant availability and elasticity of these services may encourage end users to by-pass community computing centres, thus avoiding large capital investments and long lead times to satisfy their requirements.

Cloud service providers are leveraging their internal investments – e.g., Google (search engine farms) and Amazon (compute servers and databases) – with massive economies of scale involving tens of thousands of servers. It would be impossible for the R&E community to compete head-to-head with these providers on enterprises, such as providing vanilla storage or compute services.

back to contents page

Some service providers charge for the volume of data shipped into and out of their cloud. For data-intensive applications, these costs could be prohibitive unless some agreement is reached. A possible solution would be to peer with the cloud providers at open access points on the NREN networks, hence minimising the data-movement costs.

Becoming proficient at using cloud facilities is not without difficulties. Since cloud services are not yet fully standardised, learning how to use one cloud service does not mean that it is a simple matter to move to another. NRENs could provide value to the community by developing independent best-practice guides and providing training. NRENs could also negotiate on a national or pan-European level to ensure that users obtain the services they need, including the use of community federation systems as a convenient and secure means of access.

Cloud service providers sell portfolios of services driven by their marketing strategies. If requirements fall outside of this portfolio, it is unlikely that single institutions will have sufficient negotiating power to get what they want at an economic price. NRENs could operate as a trusted and knowledgeable broker on behalf of the community, and secure the best services at the best prices.

Should the R&E community develop and build its own "community cloud" to provide levels of performance and assurance unobtainable in the commercial sector? Features that could be offered by a "community cloud" include federated access, high levels of security and privacy, guaranteed geographic storage location, and high transmission speeds without a volume charge. A number of NRENs expressed a positive interest in pursuing this idea further.

Authorisation and Authentication Infrastructures and Middleware

Middleware is sometimes called plumbing because it connects applications and passes data between them. Although AAI is a very important aspect of middleware, other important components deserve increased attention in the future. However, AAI is a particular class of middleware, in which the R&E and NREN communities excel.

The R&E and NREN communities' skills and experience in the field of AAI are a major strength. AAI systems have been developed for many federations and, in turn, have been confederated to an extent unseen in the commercial sector. These simple-to-use and robust AAI systems are vital to ensure good access to services and information repositories in a secure way.

In addition, AAI will need to be integrated into the network layer if secure user-/application-driven dynamic network configuration is to become widespread.

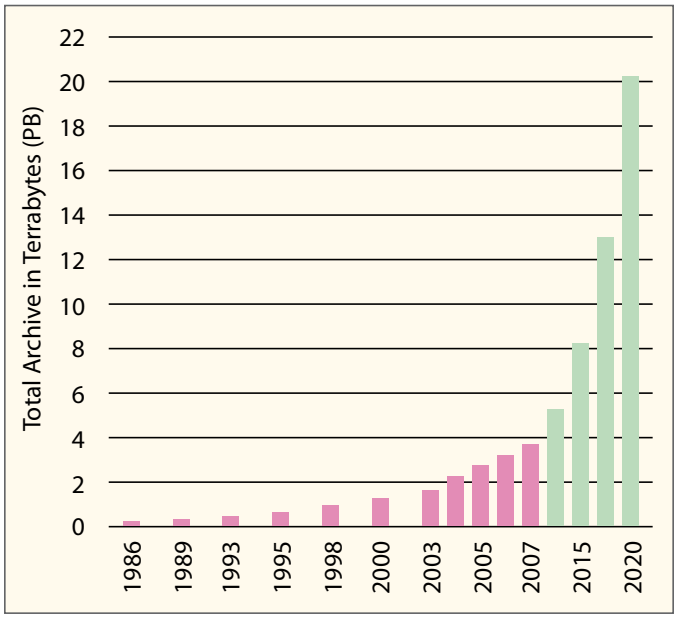
NRENs should capitalise on their lead in AAI and collaborate with the commercial sector to bring the benefits to a wider community.

In future, discipline-specific middleware will be needed for applications in genetics, astroscience, libraries, and the arts and humanities. Such middleware would be able to convey ontologies that carry semantic meaning. There is scope for the NRENs to turn their skills and expertise to other middleware areas, such as at the network layer and in discipline-specific systems that are able to convey research and semantic attributes.

back to contents page

The Data Deluge and Associated Services

There is general agreement that the volume of data being generated and stored is growing at a very high rate and that this rate is likely to accelerate. Much of this data is generated in the research community.



Evolution of European Space Agency data archives[vi]

Curating this data to ensure longevity of availability and ease of access is a major challenge. As explained in the High-level Expert Group on Scientific Data submission to the European Commission, "Riding the wave" (discussed on p. 23 of this report), there is much to be done in this respect.

The R&E and NREN communities can have a key role in delivering many of the recommendations in the submission, particularly:

- with the involvement of librarians, topic specialists, data-storage and AAI experts, the community can set about developing an international framework for a collaborative data infrastructure;
- the community can develop appropriate middleware standards and prototypes to pilot the above.

Mobility

During the past few years, technological developments have led to the shrinking of the user access interface into powerful, hand-held, Internet-connected smartphones and tablets. In addition, information and compute sources are becoming increasingly available on the Internet and hence to mobile users of such devices. In parallel, much human activity, including R&E, is becoming globalised. Researchers and students move between organisations and countries to undertake their work, some of which may be in the field, and outside of institutional boundaries. Therefore, it is vital that seamless mobile access be available, wherever, whenever, however it is needed – be that in a laboratory or on the top of a mountain.

The challenge is to provide simple, yet secure, user accreditation and service across the range of mobile technologies, such as Wi-Fi, WiMAX, 3G/4G and other new technologies as they emerge. This should include access to collaborative tools, sensor networks, instruments, and data repositories. The strength of the NRENs in this respect should not be underestimated – success in eduroam®, the deployment of eduGAIN and the pioneering work that has been undertaken in Moonshot.

back to contents page

Social Media

Some social media tools originated in the academic community, while others had their origins in the commercial sector. Usage of most of these tools touches all segments of users around the globe (Facebook currently has in excess of 600 million users, worldwide). Most of the innovative development in the social media space is taking place outside of the R&E community.

Many individuals and groups within the NREN and R&E community make use of a range of social media tools to support their work. These tools have an important role in education and research, although the R&E community has not been deeply involved in their development. NRENs should play a role in ensuring that good federated access to such tools is made available in a consistent way.

NRENs should also play a role in providing the community with independent advice and with training, so that their communities can extract the maximum value from their use of social media.

The Future of NRENs

NRENs have grown from best-effort, experimental projects to mature, business-oriented organisations capable of delivering a range of reliable services that support the mission-critical activities of their users and end-institutions. In some respects, many NRENs now resemble commercial Internet Service Providers (ISPs).

If NRENs cannot offer services that are unobtainable on the market, or services that are demonstrably better and/or cheaper than those provided by the commercial sector, it is hard to justify their continued existence. NRENs need to identify niche (specialist) services that are targeted at their user community and are not provided by commercial ISPs.

An example of a niche service is the provision of a suitable substrate to the few very heavy users of networks with special requirements for real-time throughput and exceedingly low jitter (e.g., high-energy physicists and astronomers). These are the "Class C" users in the model proposed by Cees de Laat in 2005[vii]. It is likely that "Class C" users will need NRENs to provide multi-domain advanced services for the foreseeable future. A more complex question is whether NRENs will also support "Class A" and Class B" users in the increasingly commoditised networking market. The seamless integration of services and the added value of "belonging to the community" will have some place in the decision-making process. The solution may be a mixture of NREN and commercial ISP services, integrated and brokered through the NRENs.

Authentication and Authorisation Infrastructure (AAI) and its confederation at the continental and global level are prime examples of an area where the NREN community is significantly different from the commercial sector (at the moment). The ability to deploy AAI systems widely is a major strength of NRENs and a capability that is not generally available in the commercial ISP sector. NRENs need to capitalise on this leading position and collaborate with the commercial sector to move AAI into the mainstream. NRENs could and should play a large role in making this happen.

An important characteristic of the NRENs is that they arose out of the community to serve the community. As a consequence, NRENs are much more able to understand the needs and motivations of users in the community than commercial vendors. Commercial ISP/service providers may take many months before they fully understand community requirements and translate them into practical service offerings, while NRENs should be in the position to act quickly, using their greater understanding of the requirements and providing tailor-made solutions in a timely manner. In general, NRENs have a greater understanding of the service imperatives of the community, whereas commercial organisations, by definition (and by law), are required to focus primarily on generating a return on investment for their shareholders. Thus, they are generally less flexible and are unwilling to modify contracts or services mid contract, or to develop low-volume service offerings.

back to contents page

Many NRENs have grown their customer portfolios, serving new user groups that are related to the core research and education user. These new user groups can include e-Health, e-Culture, e-Government, and science parks. There are many economic, technical, and social benefits in sharing NREN expertise (which has been funded largely from the public purse) with related organisations, provided the boundary of this enlarged community is well defined.

An expansion of the scope of R&E networking is underway in the United States of America, centred around Internet2. The U.S. Unified Community Anchor Network initiative (U.S. UCAN) has the mission to provide advanced broadband capabilities and services to the anchor institutions of the community, including public safety organisations, public libraries, K-12 schools, community colleges, research parks, and healthcare organisations. This will unlock next-generation Internet-based applications that promise to provide a whole range of new possibilities and new economic opportunities for citizens. A European initiative along similar lines would most certainly deliver similar benefits for European citizens.

In summary, NRENs should:

- intensify their links with and understanding of their user communities, including those involved in planning the future Internet;
- clearly demonstrate the value and advantage they deliver;
- aggregate community demand between themselves, both on a pan-European scale and also nationally for their own user community;
- continue to expand their user communities into related sectors;
- not compete with commercial and commodity service providers, but instead, they should collaborate to deliver maximum value and utility to users.

National members of TERENA at 30-11-2012[viii]

The outcome of the consultation workshop resulted in the choice of the four topics to be studied during the ASPIRE Project. The reports produced by each study group are summarised in the next chapter.

back to contents page

5. ASPIRE TOPIC REPORTS

The four panels of experts worked as subgroups during the period of the project and produced their reports independently, though with central coordination through the ASPIRE team in the TERENA Secretariat. The full reports are available online and represent comprehensive studies on the subject matter.

Summaries of the reports, their conclusions, and recommendations are provided in this chapter.

Adoption of Cloud Services

The cloud services study focuses on the question of how higher education and research can benefit from the adoption of cloud services.

The authors believe that cloud services offer higher education and research organisations the opportunity to provide their users with a wider range of relevant IT services at an accelerated pace and to fulfil user demand.

IT departments can use the instant availability and elasticity of cloud services to modify their expenditure profile, reducing the need for periodic and large capital expenditure to a smoother, increased, but predictable operational expenditure.

back to contents page

Furthermore, the authors of this report see opportunities for NRENs to enhance the quality of cloud offerings (by facilitating the procurement and delivery of cloud services at the right conditions), and to provide more coherence between them (by means of a middleware cloud collaboration infrastructure). To be able to do this, NRENs should embrace and make use of:

- the consumerisation of IT: users are choosers (IT departments facilitate the users);
- the power and scale of the cloud distribution model (the profound changes in the way providers deliver their services);
- the sense of urgency and interest in clouds (the desire of stakeholders to see the adoption of cloud services).

There are two routes to be taken:

- acquisition of services offered by commercial vendors in the public cloud (commodity services);
- development of services, together at NREN level, in a community cloud (services for the specific needs and special requirements of the higher education and research community).

Both routes are valid and relevant, but call for a different organisational approach.

Issue

The Cloud services are changing rapidly, offering users new ways of obtaining the services they want in an easy and often economically attractive manner. Users are making these choices now, and there is a real danger that if NRENs and institutions do nothing, users will drift into fragmented islands of incompatible services that may not have a sustainable future.

Recommendation

There is an opportunity for the NRENs to lead in the field of cloud brokering and cloud middleware infrastructures. To be able to connect the clouds and provide added value to their users, NRENs must join forces and collaborate, as they have done for many years in the area of networks. NRENs should work together on:

- consuming the public cloud: aggregating demand, vendor management and cloud brokering;
- producing business cases for community clouds;
- connecting the clouds, by means of collaboration infrastructures and federations;
- dealing with legal issues (on an EU level), standardisation, data protection, data integrity, security, and interoperability.

Adoption of Mobile Services

NRENs have traditionally focused on fixed networks and connectivity for their clients, including university campuses, research centres, and large scientific instruments. Within these structures, the NREN client has provided the access network, largely through wireless networking.

The trend towards "bring your own device" has accelerated the move towards wireless networking on campuses, predominantly Wi-Fi. Through eduroam®, NRENs have interconnected the campus islands to some extent, and have enabled greater mobility between them. Now they have an opportunity – a challenge – to provide seamless and ubiquitous services to the education and research communities at national and international levels.

Individually and together, NRENs need to grasp this opportunity and do for users what they (the NRENs) and GÉANT have done for the research community, that is, to provide an integrated pan-European campus on which students and teachers can take full advantage of all the resources available to them, including location-aware systems.

back to contents page

GÉANT has started a study of wireless networking and is working closely with its NREN partners on this. e-Learning will become an essential component of higher education, and NRENs are well placed to lead the way towards a secure and reliable wireless service for academia.

The panel identified a number of issues and made recommendations, as summarised below.

Issue

The wireless connection of mobile devices is becoming an increasingly important way of gaining access to the network, and many users expect to use their own devices. eduroam® has been a great community success due to its ease of use, federated access and protection of end-user credentials. eduroam® represents a system around one-tenth the size of the major roaming service operators, so has some significance in the market. However, coverage within the community is not uniform and user-awareness is often quite low.

Recommendation

NRENs and institutes should start planning to meet the needs of a rapidly increasing number of mobile devices, both in numbers and increased functionality. The GN3 Campus Best Practice documents[ix] provide guidance in this respect.

Concerted effort should be made by the NRENs to roll out eduroam® as widely as possible, underpinned by awareness campaigns.

The community should become more influential in the wireless sector through joining appropriate Wi-Fi industry associations and influencing standards through bodies such as IETF. Additionally, it is important that regulatory authorities understand the future wireless/mobile requirements of the community.

Issue

The introduction of Long Term Evolution (LTE) networks provides opportunities to enhance ICT services for education and research. More bandwidth, lower round-trip times, and uniformity, in combination with broad coverage, will be of great value to the users. Since LTE is a data-based service, there is a real possibility of integrating federated access, such as that used in eduroam®. There could be opportunities for Wi-Fi/LTE integration and for utilising the fixed network capacity of NRENs for the backhaul of community traffic.

Recommendation

The community should work with LTE providers to explore innovative solutions for the integration of Wi-Fi and LTE for use on and off campus. This could include the use of the fixed network capacity of the community for the backhaul of community traffic.

Issue

The NRENs have a long and successful record of implementing fixed line connections. NRENs have developed eduroam® as a global, albeit patchy, wireless connectivity system. Individual NRENs have undertaken collaborative work with mobile operators and, in some cases, have negotiated financially attractive arrangements for their users.

Recommendation

The community of NRENs and connected institutions must work towards the close integration of fixed and various wireless technologies to provide the end user with a secure, economic, and transparent service, irrespective of location.

back to contents page

Issue

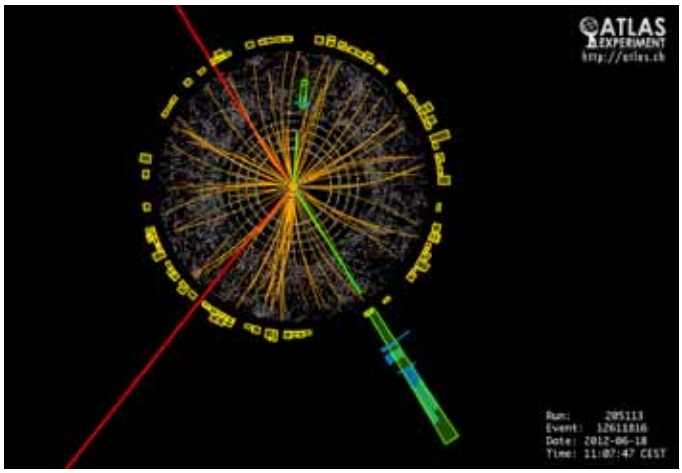
In the education and research communities, ICT has long been embraced as a powerful tool for academic progress and excellence. Mobility has added a new dimension to the learning experience, and also to research capabilities. The combination of Wi-Fi, 3G/4G and GPS, for instance, transforms the smartphone or tablet into a delivery system for enriched learning experiences.

Recommendation

NRENs should work with their institutions and others to exploit capabilities, such as location awareness, sensor availability, secure and unique identification per device, interactive electronic books, and federated access to learning resources.

Middleware and Managing Data and Knowledge in a Data-rich World

The report explores the important aspects of the handling and storage of data in the context of future research networks and the associated services. It encompasses networking requirements, storage, middleware, data policies, and data origin, each of which is considered from the standpoint of five disciplines: Genomics, High-Energy Physics, Digital Cultural Heritage, Radio Astronomy, and Distributed Music Performance.



From the specific requirements of each discipline, it has been possible to identify some common requirements for NRENs, GÉANT, and others involved in providing network connectivity. The challenge is to ensure collaboration between originators of data, users, and those who preserve and provide access to the data, and to address these requirements in an efficient manner.

The panel identified a number of issues and made recommendations, as summarised below.

http://public.web.cern.ch/public/

Issue

The amount of data collected and stored is increasing exponentially, along with the related need for the bandwidth to transport the data in order to make it available to researchers and users[x]. Because the capacity, throughput, jitter, and delay requirements of the network can be stringent, commercial network providers cannot make these connections available quickly and at an affordable price.

Recommendation

NRENs, GÉANT and others involved in providing network connectivity need to collaborate with the user communities to ensure that the networking requirements associated with the deluge of data are well understood. Adequate network services need to be put into place in a timely and economically viable manner. Aspects, such as speed of provision, throughput, privacy, persistence of connection, security and other important parameters need to be addressed.

back to contents page

Issue

Many disciplines create their own standards for data storage and, consequently, create their own middleware and applications. Due to the incompatibility of the datasets, scientific disciplines cannot benefit from the common generic developments that would be possible if cross-discipline standards were adopted.

The increased move towards "open-data" and the improvement of e-Infrastructures bring with them new possibilities for cross-disciplinary research. This approach will be hampered by the local, discipline-specific nature of datasets, middleware, and applications.

Many originators of data add metadata at the moment of creation. However, since many public and private standards are available, there is a considerable chance of incompatibility across disciplines and even within disciplines.

Recommendation

Define standardised datasets in order to benefit from the economies of scale that would follow from the availability of generic, cross-discipline middleware. Define standardised datasets, metadata, middleware, and applications for easier accessibility of data. Adopt a common metadata standard that takes the multi-disciplinary use of data into account.

Issue

Even though there is a strong desire to hold data in the public domain[xi], it is necessary to safeguard some resources for privacy, commercial, or legal reasons. A pervasive Authentication and Authorisation system is required to provide a scalable system of protection that will establish authorisations at the appropriate administrative level.

Recommendation

Adopt a globally recognised Authentication and Authorisation Infrastructure (AAI) based on recognised standards for the exchange of assertions and security tokens that can be utilised by all user communities, e-Infrastructure providers, and ICT service providers.

Examples include eduroam®, a system dedicated to the single purpose of authenticating network access, and eduGAIN, which is increasingly being used to connect interfederations.

Issue

With the massive increase in the volume of data and increasingly open accessibility, it will be necessary to be able to understand the provenance of the data along with any manipulation or processing that may have taken place. It would be helpful to researchers to be able to ascertain whether data have come from a particular instrument, whether they have been processed, or whether they have originated from other sources.

Recommendation

Create common mechanisms and procedures for all disciplines to certify and authenticate data. This could include automated signing of data before they leave the instruments where they are created, whether the instrument is a large device, such as the LHC or SKA, or a smaller device, such as a camera or scanner.

back to contents page

Issue

All disciplines have a need for the preservation and curation of data. Currently, much of the decision-making process in selecting what should be preserved and/or curated is undertaken by human appraisal. Human intervention in this way is not scalable in the longer term.

There is an increasing tendency to make the results of publicly funded work "open data" that is accessible by all. Whilst this is a laudable development, there may be issues of ethical or social sensitivity, legality, intellectual property rights, or other reasons for keeping some data protected from public access.

If datasets are to be maintained for long periods or indefinitely, continued funding will be required.

Recommendation

Facilitate collaboration between disciplines to create common policies, procedures, and tools to assist in the curation of data and the selection of data for preservation.

Future Roles of NRENs

The NREN Futures Study reviewed the current state of NRENs in Europe, and from this, made recommendations as to how the NRENs should develop to take advantage of developments in technology and business practice in the next five to ten years.

The study used a variety of methods: questionnaires, surveys, interviews and the expertise of the panel members to collect and analyse the current status, and then to predict how the NREN environment is likely to change in the future. A remarkably consistent view of future developments emerged from the different parts of the study, which details a range of recommendations and findings.

Because the state of development of the NRENs differs widely, the list of recommendations will be applicable to individual NRENs in different ways and should be adapted and adopted by the NRENs as they deem appropriate.

back to contents page

The panel identified a number of issues and made recommendations, as summarised below.

Issue

The number of bodies and committees involved in discussing policy and management of the NREN/European R&E networking sector is large. Although there is some cross membership and liaison, the consequence is too many meetings, resulting in inefficiency and duplication.

Recommendation

The European R&E networking community (NRENs, DANTE, TERENA, and user stakeholders) needs an efficient strategic management body that is able to act as a single point of contact and to respond quickly and with authority.

Under the auspices of this body, a high-level task force should be created in which decision-makers work together to define a single strategic vision for pan-European R&E networking. Failure to achieve this may lead to the fragmentation of services.

Issue

For many NRENs, the global economic crisis has intensified the issue of ensuring the sustainability of funding. Governments and the institutions that fund them are seeking ways to cut their expenditure. In some European countries, this is leading to the development of Public Service Networks, intended to serve a range of publicly funded institutions.

Dependence on periodic funding injections and money from short-term projects can be problematic for NRENs, and can hinder them in running reliable, long-term, stable services.

Recommendation

NRENs should re-consider their funding models and move to more diversified and sustainable models. This could embrace close collaboration with Public Service Networks but may require re-framing of some regulatory positions, such as connection policies and acceptable use policies. A major goal should be to increase inter-institutional collaboration, aggregation of demand, joint procurement, and sharing of services.

Issue

NRENs will find themselves operating in a harsher world than in the past. Commercial providers are becoming capable of providing many of the basic services once provided by the community. It is vital for NRENs to fully understand their operating environment, and to adapt if necessary, if they are to survive – and indeed to thrive.

Recommendation

NRENs should review their senior management structure and process to ensure that there is suitable succession-planning in place, and that those new managers have suitable management skills and vision. To compete with the commercial world, NRENs need to adopt commercial skills and policies.

NRENs need to take a strategic approach to their business planning and service delivery, and develop a thorough understanding of their own user base, including the needs of their international users and the external operating environment.

A European user-requirements compendium should be developed by TERENA, so that the R&E network providers have a strategic view of the demand side of the sector.

NRENs should not compete with the commercial providers, particularly on price. They should act as a trusted broker that is an integral part of the community by providing expertise, aggregating demand, and adding value through negotiation – including the integration of support for community AAI systems.

back to contents page

back to contents page

6. STAKEHOLDER WORKSHOP, SEPTEMBER 2012

Introduction

Following on from the initial consultation workshop in Berlin in May 2011, which set the framework for the main project activities, a second stakeholder workshop was arranged for September 2012 in Brussels. The purpose of the workshop was to allow the important stakeholders to have an opportunity to add their voice to the final recommendations of the study.

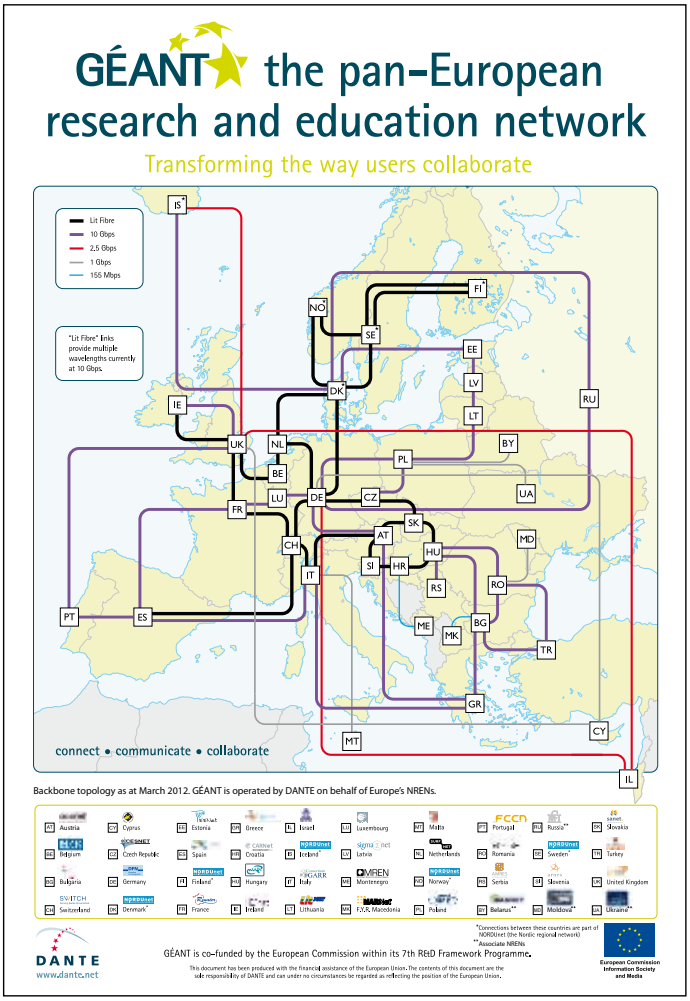
The reports of the four topic studies were made available before the workshop and presentations by each of the topic leaders were given at the start of the workshop. These presentations provided valuable input into the discussions and conclusions during the day.

The workshop was introduced by John Dyer, the ASPIRE Project Manager, along with Jean-Luc Dorel (Project Officer in Unit C1 e-Infrastructures, DG-CONNECT). Key points from the European Commission were outlined by Jean-Luc, covering the forthcoming Horizon 2020 programme[xii] for communications in Europe. There were intimations that the views on communications held by the R&E community may be at variance with those of politicians, for whom roads and transport may be higher priority than telecommunications for the R&E community.

As in most things, the status quo is not an option and the community must adopt and adapt to new funding and structural arrangements whilst continuing to provide key services. Such topics as the digital divide, GÉANT as a global hub, and innovation must be addressed in the forthcoming funding programme.

back to contents page

The Connecting Europe Facility[xiii] is to focus on a broadband networking system for public administration, modelled on the GÉANT network and replicating what the R&E community are doing. Budgets are being defined currently and first implementations are planned 2014 - 2015.



http://www.geant.net/Media_Centre/Media_Library/PublishingImages/1084_GEANT_Topology_03_12_hi_res.jpg

Presentation of the Study Reports

The four ASPIRE study topics were presented by their leaders and a short discussion was held on each. The meeting then split into several breakout groups to analyse, discuss, and report back on the studies.

Details of the four studies are provided in Chapter 5 of this ASPIRE report.

Discussions and Conclusions

The group and general discussions were very wide ranging but focused on the services that the NRENs currently provide and could possibly provide in the future as the worlds of information technology and telecommunications start to merge, namely:

- digital divide;
- funding issues;
- differentiated services and differentiated cost models;
- consumerisation;
- playing to the strengths of existing NREN services;
- community-based services, contrasted with commercial services.

back to contents page

A number of presenters focused on the strengths and weaknesses in the way NRENs perform at present and identified many of the good things that they do, as well as a number of things that should be addressed in the future. As in most things in the IT world, networking services are changing and developing at an increasing rate and user demands are also increasing and becoming more diversified. There is a potential gap between the users and the NRENs as service providers. The users are not always aware of the potential services provided by NRENs across Europe, and the NRENs are not always aware of the requirements of large groups of researchers. Clearly, there is a lot of work to be done in bridging this gap; NRENs must be more proactive in letting their users know what can be done, not only in their own country, but across the whole community. Similarly, work needs to be done to find out what the users really need and how to provide solutions in a timely manner.

Within the user community, there is a new generation of Chief Information Officers (CIOs) who may have different backgrounds from their more technical predecessors. These CIOs may not have an appreciation of the levels of cooperation that have existed between the users and NRENs and may look at services in a more business-like manner, taking costs and services into greater account. This also applies to commercial operators, who are unlikely to precisely understand the R&E user community. NRENs need to be agile in all aspects of their business, and actively communicate with their direct and indirect users to advocate the use of NREN services. There is a distinct possibility that the existing digital divide may be exacerbated if there is fragmentation in the user community.

The perception of community-based service providers, such as the NRENs, needs be changed. Very often they are perceived as slow, lumbering organisations encumbered by red tape and procedures, but there are some examples of great agility in taking innovations to the market. An example of this is the TERENA Certificate Service. Another example is the success that the R&E community has had in defining standards in the area of cross-border, multi-domain networking. These successes should be used to build confidence in the user community (market) and ensure that the concepts of collaborative networking are fostered across the board – from the individual researchers to the decision-makers and politicians who define budgets and strategies.

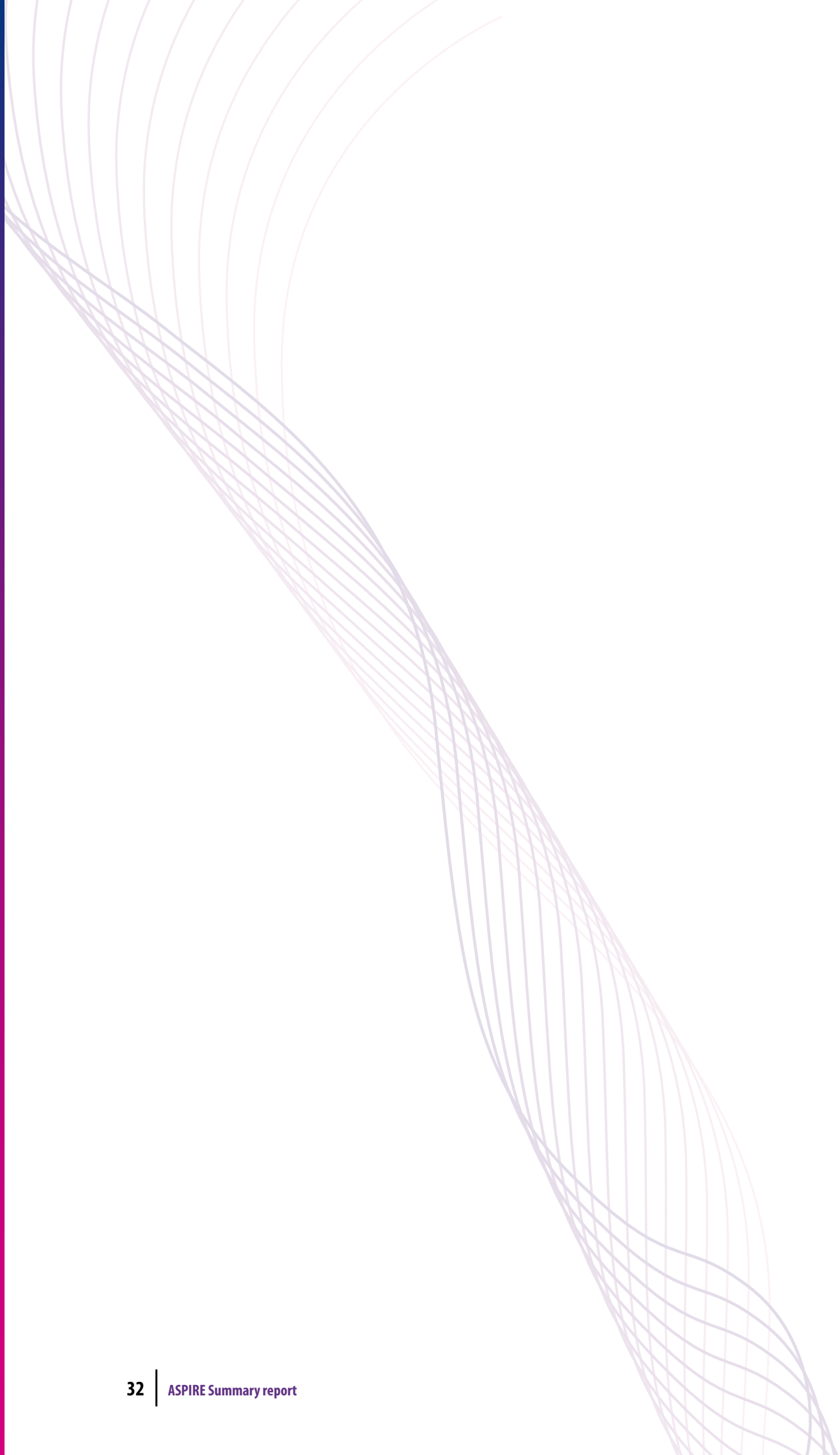
Bridges need to be built between a number of islands in the community and between the various multi-national groups that use networking and data services. Once again, the solution is to let the individual users know what is done by the NREN community and how services can be provided. Too often, the user re-invents services tailored to his own requirements, only to find that such services could have been provided more cheaply and quickly through community activities. The NREN community across Europe has a wealth of services at its disposal that other NRENs are probably aware of, but the users of each NREN must be made aware of the entire portfolio of services offered.

Technical solutions are not the only way to innovate: education and training are vital components of NREN services, both at the national level and the European level. In fact, this is a unique selling point for the NRENs and they should capitalise on this in the R&E community.

There is a range of newer services to be provided, such as the aggregation of higher-level services through negotiation with the commercial providers at national or international levels. Economies of scale can be achieved by bulk purchasing and resale to individual NRENs. Such activities do not have to be driven top-down but can be arranged by groups of NRENs acting in concert. This does require a shift in the way that NRENs work, and they will need to change to their business models in order to provide higher-level services.

The governance model of European R&E networking works, partly because there is a large overlap between the leaders in the various organisations, but a major change is required to ensure it functions in a more clearly defined and planned manner and with appropriate structures. From the outside, it could appear that the various groups are working divergently, rather than converging.

back to contents page



back to contents page

7. FINDINGS AND RECOMMENDATIONS OF OTHER STUDIES

The purpose of this section is to document what other studies and groups have been presenting and to reinforce the findings of the ASPIRE Study by pointing out common threads and recommendations in the other studies.

The following sections are extracts from key documents that were identified in the ASPIRE Study.

All of the documents are publicly available and most were funded by the European Commission. These extracts have been taken directly from the documents, without explicit permission. Copyright remains with the authors of the various original works. Some minor editing has been performed to maintain the context of the extracts, but no other changes have been made.

High-level Expert Group on Scientific Data: Riding the wave – How Europe can gain from the rising tide of scientific data[xiv]

(Final report of the High-level Expert Group on Scientific Data, a submission to the European Commission, October 2010)

This report discusses the enormous growth in the amount of data, the changing ways in which data are used, the trust needed between all stakeholders, and the funding requirements. It provides a vision and recommendations for a global framework for data handling.

back to contents page

A fundamental characteristic of our age is the rising tide of data – global, diverse, valuable, and complex. In the realm of science, this is both an opportunity and a challenge. This report, prepared for the European Commission's Directorate-General for Information Society and Media, identifies the benefits and costs of accelerating the development of a fully functional e-Infrastructure for scientific data – a system already emerging piecemeal and spontaneously across the globe, but now in need of a far-seeing, global framework. The outcome will be a vital scientific asset: flexible, reliable, efficient, cross-disciplinary, and cross-border.

The benefits are broad. With a proper scientific e-Infrastructure, researchers in different domains can collaborate on the same dataset, finding new insights. They can share a dataset easily across the globe, but also protect its integrity and ownership. They can use, re-use and combine data, increasing productivity. They can more easily solve today's Grand Challenges, such as climate change and energy supply. Indeed, they can engage in entirely new forms of scientific inquiry, made possible by the unimaginable power of the e-Infrastructure to find correlations, draw inferences, and trade ideas and information at a scale we are only beginning to see. For society as a whole, this is beneficial. It empowers amateurs to contribute more easily to the scientific process, politicians to govern more effectively with solid evidence, and the European and global economy to expand.

However, there are many challenges. How can we organise such a fiendishly complicated global effort without hindering its flexibility and openness? How do we incentivise researchers, companies, and individuals to contribute their own data to the e-Infrastructure – while still trusting that they can protect their privacy or ownership? How can we manage to preserve all this data, despite changing technologies and needs? How can we convey the context and provenance of the data? How can we pay for it all?

Our vision is a scientific e-Infrastructure that supports seamless access, use, re-use, and trust of data. In a sense, the physical and technical infrastructure becomes invisible and the data themselves become the infrastructure – a valuable asset, on which science, technology, the economy, and society can advance. Our vision is that, by 2030, the following will have been achieved.

- All stakeholders, from scientists to national authorities to the general public, are aware of the critical importance of conserving and sharing reliable data produced during the scientific process.
- Researchers and practitioners from any discipline are able to find, access, and process the data they need. They can be confident in their ability to use and understand data, and they can evaluate the degree to which that data can be trusted.
- Producers of data benefit from opening it to broad access, and prefer to deposit their data with confidence in reliable repositories. A framework of repositories will work to international standards and ensure they are trustworthy.
- Public funding rises, because funding bodies have confidence that their investments in research are paying back extra dividends to society through increased use and re-use of publicly generated data.
- The innovative power of industry and enterprise is harnessed by clear and efficient arrangements for the exchange of data between private and public sectors, allowing appropriate returns to both.
- The public has access to and can make creative use of the huge amount of data available; it can also contribute to the data store and enrich it. All can be adequately educated and prepared to benefit from this abundance of information.
- Policy-makers are able to make decisions based on solid evidence, and can monitor the impacts of these decisions. Government becomes more trustworthy.
- Global governance promotes international trust and interoperability.

There is a clear role for government in all of this; we offer a short-list of action by various EU institutions – building on work already begun across the EU in recent years, and complementing efforts in the US, Japan, and elsewhere in the world.

back to contents page

1. **Develop an international framework for a Collaborative Data Infrastructure.**

   The emerging infrastructure for scientific data must be flexible but reliable, secure yet open, local and global, affordable yet high-performance. There is no one technology that can achieve it all, so we need a broad, conceptual framework for how different companies, institutes, universities, governments, and individuals would interact with the system. We call this framework a Collaborative Data Infrastructure, and we urge the European Commission to accelerate efforts – in Europe and around the globe – to make it real.

2. **Earmark additional funds for scientific e-Infrastructure.**

   Development of e-Infrastructure for scientific data will cost money, obviously – and as there is a significant element of public good in this, so there must be a significant degree of public support. One obvious source is found in the EU's Structural Funds – a portion of the budget mostly used to build roads, industrial parks, and other key infrastructure, targeted at those regions of Europe most in need. Already, a portion of this budget is earmarked for research and innovation, including digital infrastructure. We call upon the European Council to expand the funding possibilities.

3. **Develop and use new ways to measure data value, and reward those who contribute it.**

   If we are to encourage broader use and re-use of scientific data, we need more, and better ways to measure its impact and quality. We urge the European Commission to lead the study of how to create meaningful metrics, in collaboration with the "power users" in industry and academia, and in cooperation with international bodies.

4. **Train a new generation of data scientists, and broaden public understanding.**

   We urge that the European Commission promote, and that the Member States adopt; new policies to foster the development of advanced-degree programmes at our major universities for the emerging field of data scientist. We also urge the Member States to include data management and governance considerations in the curricula of their secondary schools, as part of the IT familiarisation programmes that are becoming common in European education.

5. **Create incentives for green technologies in the data infrastructure.**

   Computers use energy, and as the tide of scientific data rises further, the energy consumption risks rise in tandem. We urge the European institutions, as they review plans for CO2 management and energy efficiency, to consider the impact of e-Infrastructure and prepare policies now that will ensure we have the necessary resources to perform science.

back to contents page

e-IRG White Paper 2011[xv]

The e-Infrastructure Reflection Group (e-IRG) is an inter-governmental policy body comprising government-appointed delegates from thirty-one Member States, as well as representatives from the European Commission. Recommendations from the e-IRG 2011 White Paper are included below.

e-Infrastructure governance: from management and international aspects, to legal and financial issues

- Establish a user-community-centric approach in strategic e-Infrastructure governance. This should include the appropriate funding mechanisms that make a clear distinction between the funding of service provision and the funding of innovation activities.
- Define the long-term financial strategy for e-Infrastructures aimed at a sustainable operation of services in a flexible and open environment that includes offers from commercial service providers.
- Address the problems of barriers to cross-border service delivery and quickly remove as many of these as possible.
- Introduce governance models that provide efficient and effective coordination mechanisms at all levels: regional, national, European, and – where possible – global, while providing the possibility for public and private research and cooperation via public-private partnerships (PPPs).
- Encourage important players in the use of e-Infrastructures, such as ESFRI, Virtual Research Communities, to investigate the impact of strategic changes in the governance and financing of e-Infrastructure and on the operation of and access to international research infrastructures.
- Investigate the effectiveness of legal structures, such as ERIC, for e-Infrastructures.

back to contents page

The future of research networking

- Innovate in network provisioning and network governance to satisfy user demand and stay competitive at the global level.
- Use the planned GN3 Foresight Study led by TERENA to draft an Innovation Agenda for research networking, to be used by all stakeholders.
- Build the networks as a federative and open system, giving flexibility and worldwide connectivity to public and private researchers and with seamless integration with other e-Infrastructure service providers.
- Rigorously investigate the causes of the digital divide between European researchers and combat this with the appropriate instruments.

Authentication, authorisation and accounting

- Continue to improve national infrastructures and their alignment with agreed standard procedures for identity management, accounting, and assurance, with the objective of technical interoperability between all national AAIs.
- Accelerate the continued integration of different identity technologies, through support of active collaboration between the IGTF, GÉANT and relevant European and international working groups.
- Require that, wherever possible, future pan-European e-Infrastructure and ESFRI RI projects define their access control policies and mechanisms from the beginning, in accordance with the standards and best practices adopted by the community.
- Draw up a roadmap to book progress for all stakeholders in unified, integrated approaches to replace existing authentication and authorisation infrastructures based on national AAIs.

Energy and Green IT

- Decrease the energy consumption of all components of the e-Infrastructure by providing a different kind of architecture and working out more efficient software-management procedures.
- Develop more efficient ways of using the provided energy by increasing the efficiency of the cooling systems and reusing the heat energy for different purposes.
- Analyse the environmental impact of various approaches to energy maintenance.
- Promote R&D on Green IT topics and provide more service-management procedures.
- Work out and promote Green IT standards at an international level, such as the Energy Star or the green grid.
- Locate data centres at optimum locations in terms of the balance between green energy and energy efficiency.

Exascale computing and related software

- Encourage the development of European hardware technology in order to compete and cooperate with the current leading countries in HPC.
- Dedicate resources to the study of new programming models, algorithms and languages, porting software libraries and software tools to exascale environments, and preferring open source software solutions to leverage existing know-how in a cost-efficient way.
- Identify new Grand Challenges in science that are able to utilise the exascale platforms.
- The partnership between users of exascale computing, industry and computer scientists must be encouraged, and scientists should be given the opportunity to liaise with programming experts.
- Specialists must create training materials, including robust and easy-to-use "cook books" for users, especially for those who are not computer scientists.
- Ensure that the value of the scientific case for exascale computing is well understood and appreciated by society at large by means of knowledge dissemination, and engagement with the public, policy-makers, and industry.

back to contents page

e-Infrastructure services

- Involve the user communities in the definition and exploitation of e-Infrastructure services.
- Use virtualisation and SOA when developing and introducing new e-Infrastructure services wherever this is efficient. Apply simplified access, transparent service offerings, customised support, standardisation, improved governance models, and sustainable business models in the definition and deployment of e-Infrastructure services.
- Promote cooperation with other public sectors in the e-Infrastructure arena, such as government and healthcare, to exploit economies of scale and intensify the contribution of research and education e-Infrastructures in facing societal challenges at large.
- Boost innovation by public-private partnership activities through the joint creation of a market for e-Infrastructure resources and services.

Data infrastructures

- Work out a step-by-step strategy for developing the European data infrastructure gradually, addressing basic issues such as data persistency, accessibility, and interoperability first, and leaving complicated issues such as privacy and legal matters (such as cross-border exchange of sensitive data) for subsequent stages.
- Implement strategy at different levels, including low-level services such as bitstream data storage, exchange in data infrastructures, content-related curation, preservation, and data exploitation services, as well as activities aimed at interoperability and data access federation and openness.
- Involve stakeholders of the data infrastructure including resource providers, existing infrastructures and initiatives and user communities in order to build reliable and robust data services suitable to real needs.

ESFRI: Inspiring Excellence – Research Infrastructures and the Europe 2020 Strategy[xvi]

Innovation is critical for Europe's future and research infrastructures are a driving force behind it.

SKA Organisation/Swinburne Astronomy Productions

Research instruments and facilities – such as synchrotrons, databases, telescopes, sensor networks, and biomedical facilities – are an unprecedented asset. There are more than 500 of them, of which at least 300

back to contents page

have strong international visibility, attracting world-class researchers. These research infrastructures represent an aggregate European investment of more than €100 billion. Some 50,000 researchers use them each year to produce 3,000 to 6,000 high-impact research papers annually – as well as a chain of patents, spin-off companies, and industrial contracts. Their know-how helps European industry develop new pharmaceuticals and high-performance materials, monitor the earth's ocean and air, and track the changing social attitudes and behaviour of our fellow citizens. They help provide the answers we will need to solve our grand societal challenges – energy supply, climate change, healthcare for all. They propel collaboration across borders and disciplines. They promote the mobility of people and ideas, and enhance quality in education.

Most important, research infrastructures inspire excellence. When well conceived, funded, and managed, they are open research institutes that draw the best scientists from across Europe and the world. They are engines to drive the rest of the European research and innovation community to excellence – the one trait we must nurture to ensure our economy remains competitive. ESFRI has been working since its inception in 2002 to spur the development, prioritisation and sustainable operation of valuable new and existing research infrastructures, and it is working now to revise its "Roadmap" of future work.

The environment for research infrastructures is getting more difficult, due to economic turmoil, compressed public budgets, and rising international competition. However, in March, the European Commission announced a plan for the Union's development – the "Europe 2020" strategy; it depends upon innovation to succeed. We see research infrastructures as central to the success of that strategy and thus, we propose a vision of where enlightened leadership can take research infrastructures through the next decades.

- By 2020, the European Research Area will have full availability of the needed world-class, top-quality research infrastructures to inspire researchers in every major discipline. The ESFRI Roadmap prioritises 44 projects at a cost of about €20 billion, and by 2015, we expect 60% of those to be launched or completed. However, quality will count: existing and new research infrastructures must be and remain open to the best scientists, judged by an effective system of international peer review to ensure the best scientific and technological returns.

- Research infrastructures in Europe will serve as high-performance platforms for cooperation among universities, enterprises, and research institutes. The resulting innovation ecosystem will spur new ideas, solutions, and innovations that are of benefit to the European economy and society, as well as to science. Special attention should be paid to nurturing the SMEs that supply them, collaborate with them, or spin-off from them.

- Effective cooperation among EU, national and regional funders will provide a stable base for building, maintaining, and operating research infrastructures. This will ensure that European research remains world-class, to the benefit of local communities and the Union overall. To that end, EU institutions should provide more funding for operation and maintenance, as well as planning and implementation. Europe must step forward to ensure that the "level playing field" for open access to research infrastructures is maintained, and to ensure coordination with the Member States.

- A strong, internationally benchmarked system of governance – both within the research infrastructures and among the national and EU organisations planning them – ensures high-quality results. For this, we need an EU-level initiative for "European Research Area Institutional Excellence", with criteria to measure quality and indicate priorities. ESFRI should evolve from its present strategic role as an incubator of research infrastructures to include an evaluation function, with a mandate to assess excellence through international peer review.

back to contents page

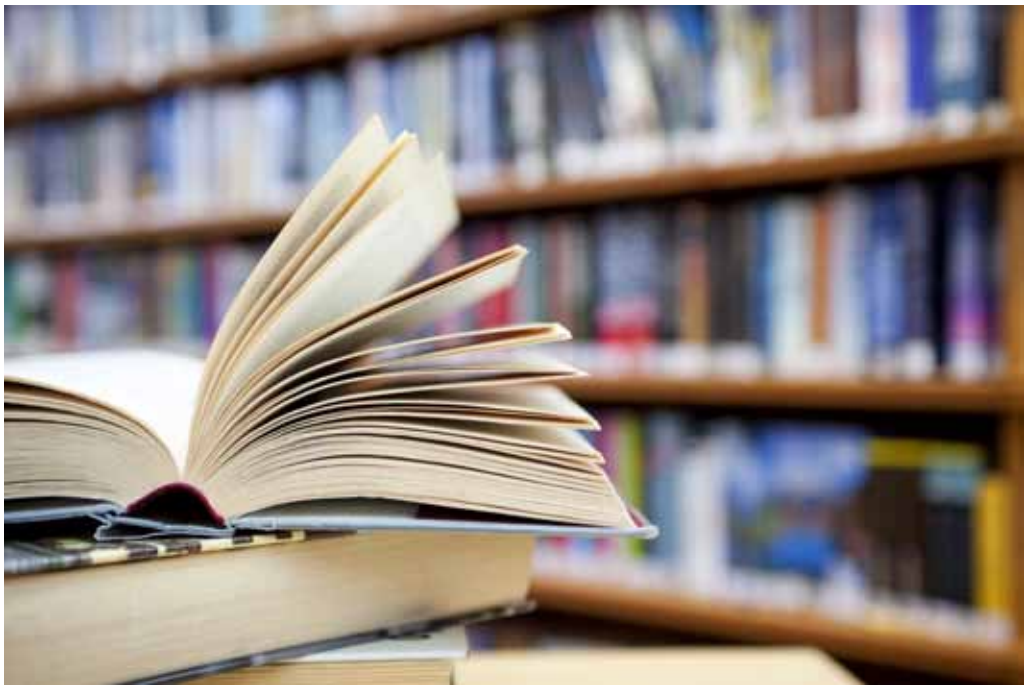
- The network of research infrastructures across Europe strengthens our human capital base – providing world-class training for a new generation of researchers and engineers, and promoting the mobility of the people and ideas embodied in the "Fifth Freedom". To achieve this mobility, more researchers and technicians should be encouraged to include research infrastructures work in their careers, and the current barriers to their mobility must be dismantled.

- Research infrastructures provide the means and impetus to develop a truly sustainable e-Infrastructure to store, share, and protect digital data. This will permit Europe to lead the development of e-Science. This will come at a cost – but expense can be managed by developing effective, international standards for preserving and allowing access to the data.

- The Grand Challenges of our time require a global response: this requires that research infrastructures in Europe are open to the world and that Europe speaks with one voice in its international negotiations for the establishment of new research infrastructures and in the exploitation of existing ones. This is recommended to speed our drive to excellence, and put us in a position to lead world research and technology.

Research infrastructures are the pre-eminent scientific tools of our age and, when pushed to pursue excellence, are engines to drive forward innovation in the EU. We call upon the EU institutions and Member States to support them in a coordinated effort, and to make this vision for 2020 a reality.

GÉANT Expert Group: Knowledge without Borders – GÉANT 2020 as the European Communications Commons[xvii]



Research and education is at the heart of the creative society

- Today's society is a creative society, more than ever a competition of ideas.
- The creative society needs infrastructure.
- The European Research Area is the organisational infrastructure for research and innovation.
- GÉANT is the communication infrastructure backbone to Europe's research and education community.

back to contents page

The creative knowledge society of 2020 will be very different

- The environment served by GÉANT – the sphere of research, innovation, and learning – is experiencing profound change.
- The nature of the scientific process is changing fundamentally, with research becoming more inter-disciplinary and data driven.
- Knowledge is increasingly being created outside traditional research organisations.
- Digital technologies are changing the nature and context of innovation across the economy.
- Technology is evolving fast and Moore's law is holding.
- The situation is critical and Europe risks losing out.

A vision for 2020 to maintain Europe's lead: the European communications commons for knowledge, innovation, and learning

- Research and innovation are central to Europe's future prosperity and well-being.
- Research and education networks provide an essential support for this engine.
- Our vision for "GÉANT 2020" is as the European communications commons, where talent anywhere is able to collaborate with peers around the world and to have instantaneous and unlimited access to any resource for knowledge creation, innovation, and learning, unconstrained by the barriers of the pre-digital world.

Specifically, the goals that fulfil the GÉANT 2020 vision are:

1. to support knowledge communities by providing world-class connectivity and services;
2. to support the growth of these communities, in both breadth and depth within Europe, and opening up to talent beyond Europe's borders;
3. to push the state-of-the-art of the communications commons by constant innovation and by translating this innovation into a competitive European ICT sector;
4. to reorganise to cope with the constantly changing environment.

Implicit in our vision statement, and common to each of the goals, are:

- GÉANT 2020 as a common, enabling infrastructure for European Research and Education
- GÉANT 2020 as a collaboration platform
- GÉANT 2020 as an environment for knowledge creation, innovation and learning
- GÉANT 2020 as a transformative digital eco-system

The four goals may be expanded as follows:

Provide world-class connectivity and services to knowledge communities

- GÉANT 2020 should enable world-class research and education at all levels and in all disciplines, and facilitate new user communities in emerging areas of science.
- The networks must evolve into service-enabled infrastructures.
- We envisage moving towards a richer mesh of networks based on ubiquitous virtualised resources.
- NRENs should be encouraged to make business decisions.
- The networks should focus on cost-effectiveness and providing what does not exist commercially.
- The networks should emphasise performance.
- The networks should maintain a chain of trust, security, and privacy.
- The NRENs should grow beyond the network.

back to contents page

Support the growth and opening up of the community

- Help to close digital divides
  - GÉANT 2020 is an instrument for inclusion in the creative knowledge economy.
  - Removing digital divides is a prerequisite for Europe's economic and social development and a key objective of the Digital Agenda for 2010-15.
  - GÉANT 2020 should look for innovative policy solutions.
- Hub to the world
  - Europe must remain a major global hub for scientific expertise in all specialties and disciplines, and a partner of choice for global scientific collaborations.
  - Europe should work as a global partner.
  - Europe should take an active role in innovation and standardisation efforts with partners in other regions so as to ensure efficient and synergistic platforms for global science efforts.
  - Europe should exploit scientific, cultural, and historic links.
- Extend the user base
  - GÉANT 2020 should continue to widen its user base, distinguishing between several constituencies, including traditional and emerging.
  - The networks should be encouraged to expand into any research and learning community and allowed into any public service function where economies of scale can be achieved.
  - Expansion should not inhibit the networks' main mission.
- Push the state-of-the-art through innovation
  - A much stronger orientation towards innovation is required, building on the networks' unique, but underutilised position within the European innovation ecosystem.
  - GÉANT 2020 should provide an influential research partner, testbed provider, and leading customer for the European ICT industry.
  - GÉANT 2020 should leverage buying power.
  - GÉANT 2020 should drive networking breakthroughs.

Reorganise for 2020

- Prepare for change
  - The organisation of the networks must adapt to reflect the new realities.
  - A federated model should evolve with flexibility and sustainability in mind.
  - NRENs should remain the key building blocks of this new structure.
  - In some cases, NRENs may wish to form clusters.
  - GÉANT 2020 should clarify the mandates, governance, and decision-making of European-level bodies.
  - GÉANT 2020 should open up innovation activities to a broader range of actors.
- Ensure flexibility in technology and architecture
  - The project should allow for flexibility in architectural choices and operational modes, recognising the increasing diversity of solutions available.
  - The guiding principles should be user requirements, contributing to the European communications commons, and giving Europe the best position in global R&E networking.
  - GÉANT 2020 should leverage existing investments while capitalising on new developments.
- Integrate experimentation, engage in standardisation
  - The project should strive to close the experimentation gap.
  - GÉANT 2020 should engage actively in global cooperation for standardisation.
- Improve the governance
  - Governance must be transparent and responsive.
  - GÉANT 2020 should ensure a stronger role for users in the governance of the networks.

back to contents page

- Step up funding
  - As a common and strategic European infrastructure, the research networks should be publicly funded.
  - Europe's public funding of the research and education networks should be stepped up.
  - The EU should fund the EU-level research and education networking infrastructure in full.
  - Member States must continue to invest in their research networks.
  - GÉANT activities (e.g., operation, innovation, and new services) (co-)funded by the EU, should be supported by fewest possible mechanisms and concentrated in the RTD framework programme.
  - High-end users must bear a greater share of the burden.
  - Budgets for innovation activities should increase significantly.
  - The NRENs should use the European Structural Funds in a more systematic way to address digital divide issues.
  - The NRENs should use the Risk Sharing Financial Facility operated by the European Investment Bank.
  - Funding on all levels should be properly planned for and stable.
- Update the regulatory regime
  - The project should align the European regulatory frameworks to NRENs' potential.
  - The project should strive to cut the costs of data roaming.
  - The project should reserve some spectrum for the research community.
  - The project should technically support mobility within the ERA.

Connecting Europe Facility: A growth package for integrated European infrastructures[xviii]

The following is an extract from: EUROPEAN COMMISSION Brussels, 19.10.2011 COM(2011) 676.

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN COURT OF JUSTICE, THE COURT OF AUDITORS, THE EUROPEAN INVESTMENT BANK, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND TO THE COMMITTEE OF THE REGIONS

DIGITAL INFRASTRUCTURES

Investing in high-speed connectivity and services provided by (or via) modern Internet networks is investing in the future. Digital infrastructures – both physical- and service-based – are key enablers for the smart growth that Europe must achieve in the coming ten years in order to ensure its ability to compete internationally and generate wealth for its citizens. Indeed, this initiative is anchored in the Europe 2020 Strategy for smart, sustainable, and inclusive growth, which put digital infrastructures at the forefront as part of the flagship initiative, "Digital Agenda for Europe". It underlines the need to ensure the rollout and take-up of broadband for all, at increasing speeds, through both fixed and wireless technologies, and to facilitate investment in the new, very fast, open, and competitive Internet networks that will be the arteries of a future economy.

The purpose of the guidelines is to establish the objectives and priorities envisaged for broadband networks and digital service infrastructures in the field of telecommunications. The guidelines further identify projects of common interest for the deployment of broadband networks and digital service infrastructures (e.g., e-Health, e-Identity, and e-Procurement). These projects will help to address the issues identified as important blockages to the development of a Digital Single Market, including, for example, the lack of broadband investment in Europe compared to our main competitors, which leaves growth-potential and societal benefits untapped. There is also a need to increase competitive pressure in the area of modern broadband networks and to develop adequate strategies to publicly support the rollout of broadband networks in areas where there is no business case. For the digital services, the blockages mainly concern the absence of technical interoperability, making it essential

back to contents page

that on-line public services stop at the border. There are no natural owners of European, interoperable service infrastructures and neither single Member States, nor private investors can ensure service deployment within interoperable frameworks. The EU added value is, thus, high.

The CEF for Digital infrastructures will support, with a mix of grants and innovative financial instruments, investments in networks capable of achieving the targets of the Digital Agenda for Europe flagship initiative of universal coverage at 30Mbps, or having at least 50% of households subscribing to speeds above 100Mbps. A balanced portfolio of 30 Mbps and 100 Mbps projects will be created and due account will be taken of Member States' investment needs, which are indicatively assessed to be up to 270 billion EURO.

For the digital service infrastructure, interoperable frameworks are financed through direct grant schemes and include, for example, trans-European high-speed backbone connections for public administrations, cross–border delivery of e-Government services based on interoperable identification and authentication (enabling e-Procurement and e-Justice as well as e-Health services), digital resources of European heritage, safety and security (safer Internet and critical service infrastructures), and smart energy services.

These projects shall contribute to improving the competitiveness of the European economy, including small- and medium-sized enterprises (SMEs), promote the interconnection and interoperability of national networks as well as access to such networks, and support the development of a Digital Single Market. In order to be able to adapt to changing political priorities, technological developments or the situation in the relevant markets, it will be possible to identify new projects of common interest in the course of the implementation of these guidelines.

back to contents page

The Reykjavik Group: Beyond the GEG report – towards the European Communications Commons[xix]

The Reykjavik Group was created by the TERENA Executive Committee to address a request from the General Assembly to organise a community response to the report of the GÉANT Expert Group (the GEG report). This is a first step to outlining a strategy to help the European research and education (R&E) networking community achieve its part in the European Commission's vision for the future of research and innovation, "Horizon 2020".

The Reykjavik group assessed the national and international roles of NRENs and agrees with the GEG report that NRENs are different from each other. That difference could even increase in the future. At the level of pan-European collaboration, the community should accept and embrace the differences, rather than trying to homogenise all NRENs, in order to best leverage their individual strengths.

However, NRENs have many things in common and together face many of the same challenges. The Reykjavik Group finds the following as the most common strategic challenges for the community:

Keep the users, users have a choice, deliver value

- Participants in the GÉANT Project should expand the existing Compendium of NRENs to include surveys on current and prospective users.
- As part of a more business-like approach to services, the NRENs and the GÉANT Project should maintain service catalogues and increase user participation in service strategy and design.
- The NRENs should consider aggregating around domain-specific competence centres at the international level.

Stay innovative, stay focused on value proposition

- R&E networking organisations should consider creating special interest groups covering areas of agreed interest and importance.
- The GÉANT Project should leverage open calls.

Address the digital divide

- R&E networking organisations should share information on how to access structural funds.
- R&E networking organisations should prepare information for the EC and local government about the competitive situation in Europe, regarding the ability of the different countries to carry out world-class research. The intention is to clearly identify the main barriers that exist in each case, concerning network infrastructures.

Ensure sustainability

- The community should engage in a review of the funding models concerning network infrastructure and share information on business models.

back to contents page

Reconsider organisation and governance for the European R&E networking community

- The General Assembly should reconsider the organisation and governance of R&E networking in Europe.
- The Reykjavik Group proposes that TERENA and DANTE come together with a joint proposition for an umbrella organisation, with the input of NRENs through advice from the Reykjavik Group or another similar body, as decided by the General Assembly.
- The first report should be prepared by the boards of TERENA and DANTE by end of December 2012. The report should define the overall process and the timeline, including consultation and decision-making, with the aim of starting implementation by the end of 2013.

Advancing Technologies and Federating Communities – A Study on Authentication and Authorisation Platforms for Scientific Resources in Europe[xx]

Supporting and promoting scientific research and innovation, as well as enabling access to scientific information, have always been key priorities for the European Commission and the Member States. It is widely acknowledged that Authentication and Authorisation Infrastructures (AAIs) play a crucial role in supporting research and in providing a distributed virtual environment where scientific resources can be stored, accessed, and shared. More interactive, collaborative approaches to research, in conjunction with the deluge of data, are opening new frontiers to data processing, storage, and preservation; this also poses new requirements and challenges for existing AAIs across Europe.

The goal of this study, prepared for the European Commission, is to evaluate the feasibility of delivering an integrated Authentication and Authorisation Infrastructure, AAI, to help the emergence of a robust platform for access and preservation of scientific information within a Scientific Data Infrastructure (SDI).

The document focuses on three key areas:

- presenting the requirements for the AAI for SDI;
- analysing the results from a state-of-the-art survey of existing AAIs;
- presenting the main challenges and recommendations.

The conclusions of the report summarise the high-priority recommendations and the actions required that should be addressed in the short term.

- **Rely on standards for federated technologies for network, service, and application access across Europe:** specific support should be given to inter-federation to meet cross-disciplinary and cross-boundary requirements and to create a common access infrastructure.

- **Enhance existing AA infrastructures to address research communities' demands for accessing different types of services in a manageable and secure way:** AAA support for mobile access; support for non-Web browser applications; development of security token translation services to enable inter-operability of different AAIs; provision of guest IdPs for users that cannot rely on an institutional IdP; allowance for effective resource-usage accounting for distributed and heterogeneous environments; enablement of the uptake and use of persistent identifiers within AAIs; support for social network identities in combination with institutional identities to address specific use-cases for the SDI.

back to contents page

- **Enhance authorisation in inter-federations scenarios by providing support for distributed attribute management:** provide security mechanisms and tools to enable Identity Federations to consume attributes managed by collaboration projects.

- **Phase-out IP-based authentication:** provide support for those institutions relying on IP-based authentication to migrate to federated access technologies.

- **Facilitate the development of a common policy and trust framework for identity management that involves Identity Federations for e-Researchers' communities, libraries, and data centres**: REFEDS to coordinate Identity Federation processes, practices and policies on behalf of R&E Identity Federations; EC to facilitate communication among different groups.

- **Expand the coverage of the Identity Federations of national federation operators**: allocate national funding to support and train communities to join national Identity Federations.

- **Implement scalable policy negotiation mechanisms**: define ways to simplify the negotiation of service agreement (services should not negotiate with each IdP, but via the federation).

- **Harmonise the policies of Identity Federations**: define guidelines for the policies of R&E Identity Federations.

- **Lower the entry level for the adoption of existing infrastructures for new users and providers and support communities to benefit from existing AAIs:** consider ways to offer ready-to- use solutions that hide technical complexity from the users.

- **Provide clarity about consent and legitimate Interest**: provide clear and simple documentations and raise awareness on when consent can or cannot be used.

- **Organise training for the Member States' representatives to avoid cultural interpretations of the Directive and to prepare for a smooth transition from the Directive to the Regulation:** raise awareness of the Directive.

- **Secure funding to work towards inter-operability of e-Infrastructures and to enhance the corresponding AAIs**: EC funding should be directed, where possible, to enhance, consolidate and harmonise established systems rather than creating new ones.

- **Secure sustainable structural funding to support various e-Infrastructures**: provide mechanisms to ensure long-term sustainability for different infrastructures (i.e., Identity Federations, Data Infrastructures, and Grids).

- **Invest in "train-the trainers" initiatives**: provide training for data professionals to provide guidance to researchers on issues, such as data privacy and intellectual property as well as to address cultural barriers to collaboration and data sharing.

back to contents page

GN3: Study of Environmental Impact – ICT Best Current Practice[xxi]

This deliverable describes a wide range of initiatives undertaken by the partners in GN3 Networking Activity 3 (Status and Trends), Task 5 (Study of Environmental Impact) (NA3 T5) to reduce environmental impacts in general, and the emission of greenhouse gases in particular.

The study provides an update to the previous deliverable (DN3.5.2: Study of Environmental Impact), expanding some of the research ideas and providing commentary on new findings. Topics covered include environmental policy, GHG audits and reports, green network management systems, Power Usage Efficiency (PUE), virtualisation, energy-aware traffic engineering, videoconferencing, distance working, Green Public Purchasing (GPP), green electricity, energy source choices or options, and disseminating green ICT in the Higher Education (HE) community.

Recommendations are also provided for each topic, which are relevant to the GN3 Project, the NREN community, their users, and the ICT sector. This deliverable also encourages NRENs to actively engage with users in Higher Education to share knowledge and experience, and it raises awareness of other international support programs that may better address user needs.

The elements of telecommunications infrastructure, such as data centres and networks, have traditionally focused on creating the best possible solutions for their clients, but have shown little or no thought for the environment in their business models. During the last few years, however, there has been a noticeable increase in environmental awareness, and NA3 T5 formed a team to increase awareness and develop best practices. This group quickly became known as the "Green GÉANT" team, which is a good measure of how these developments have raised awareness. All research and case studies described in this document follow on from the establishment of externally verified climate accounts amongst six NRENs.

back to contents page

Key recommendations drawn from the partners' work

1. A written environmental policy is a sensible, first step towards raised environmental awareness and a reduction in environmental impacts. (Only six GN3 peer NRENs are reported to have environmental policies in place, of which only two have published their policies on their websites.)

2. Establishing a dedicated green network management system, and using it to identify problem areas and potential solutions, is recommended as an operational second step. (Only one of the GN3 partner NRENs is known to have such a system in place.)

3. Despite the first two recommendations, there are no formal preconditions for making environmental improvements, even though, as the achievements of the Green GÉANT partners demonstrate, many changes are easy to implement.

4. Production of IT equipment is demanding for the environment, so ensuring a long lifetime with high-quality, needs-based functionality is crucial. Selecting new equipment, which has integrated eco power-saving technologies and that will implement new power monitoring and support sleeping mode when not in use will be essential to reduce the total lifecycle costs of such a deployment. Service demand for bandwidth is also not growing as rapidly as once anticipated, which reduces the pressure for frequent updating of networking equipment.

5. Videoconferencing remains a powerful tool for sharing information and cutting travel time and emissions. Although new advances in demonstrating medical procedures benefit from HD broadcast, solutions can also be basic, PC-based set-ups and still be effective.

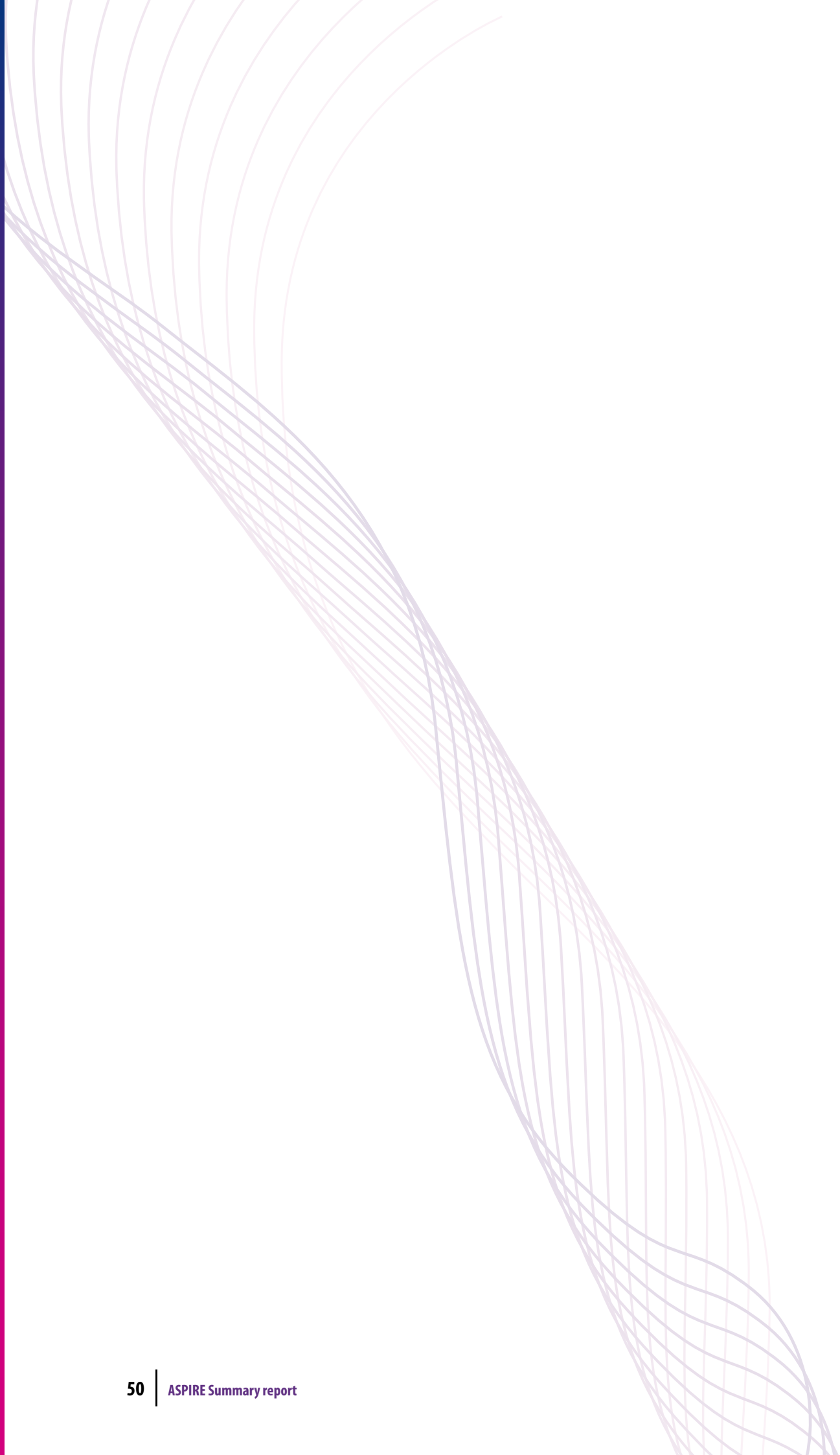
6. The savings envisioned in the SMART 2020 report require that stakeholders at all levels are aware of the possibilities provided by high-performance data centres and networks.

7. Working together is still one of the most powerful ways to combat greenhouse gas (GHG) emissions. NRENs are well placed to share information, expertise and to collaborate with partners. Supportive forums enabling such exchanges are provided by the ongoing work of the GN3 Project and TERENA.

8. NRENs are potentially well placed to take a lead in industry initiatives to promote sustainable policies.

9. The third year of the GN3 Project has shown that awareness - raising and the reduction of GHG emissions require ongoing effort. Action is now required, and there are networking tools and advances in the design of new eco-friendly semiconductors that are more energy-efficient. These energy efficient, will help improve the likelihood of reducing GHG emissions. Promotion of procurement policies that focus on environmental considerations will also help NRENs to encourage equipment manufacturers to supply more power-usage metrics and include techniques to interactively measure power consumption while the equipment is in use. We are well placed to share the learning from the project and the industry, which will ultimately result in innovative solutions for the NREN community.

back to contents page



back to contents page

8. CONCLUSIONS AND RECOMMENDATIONS

Drawing the Threads Together

The recommendations from the topic studies are reported in Chapter 5 of this report. However, the European R&E network services form part of an eco-system that is influenced by the wider evolution of R&E on a global scale: technological development, increasing commoditisation of network services and societal changes brought about as a result of the economic crisis. These additional factors must be taken into account when recommending strategies for future development of the R&E networking infrastructure. The authors of this report have consequently considered the recommendations of the ASPIRE expert topic panels in the context of the visions expressed by the following groups and documents:

- the GÉANT Expert Group (GEG);
- the e-Infrastructure Reflection Group (e-IRG);
- the European Strategy Forum on Research Infrastructures (ESFRI);
- the European Commission's proposals for the Connecting Europe Facility (CEF);
- the High-Level Expert Group on Scientific Data;
- the Authentication and Authorisation Platforms for Scientific Resources in Europe Study Group;
- the Reykjavik Group;
- the GN3 Study of Environmental Impact and ICT Best Current Practice;
- the TERENA Compendium of NRENs in Europe[xxii].

The NRENs and GÉANT

European NRENs have matured from embryonic projects in the 1980s to organisations providing highly reliable, pan-European, cutting-edge networks supporting mission-critical services. These networks are a valuable European asset, capable of supporting the e-Infrastructure projects in the solution of the remaining Grand Challenges.

During their evolution, NRENs have developed an enormous wealth of experience, knowledge, and skills. The NRENs and GÉANT networks currently provide a world-class network service to an estimated 40 million researchers and millions more students.

From a financial perspective, NRENs have an outstanding record of supporting rapid growth in traffic over many years without significant increases in budget.

If Europe is to succeed in becoming the global hub of knowledge and innovation, it must ensure its e-Infrastructure remains supported by world-class networks to empower researchers, irrespective of their location, and hence, to reduce the digital divide. This network will require sustained and stable funding to underpin its continued development.

back to contents page

Service Portfolios

Research networks have traditionally been innovators. Historically, NRENs have provided R&E users with network connectivity and services unobtainable from the market at an economic cost. The current service portfolios of European NRENs are extensive, encompassing a range of middleware and collaborative services, as reported in Chapters 5 and 6 of the 2012 edition of the TERENA Compendium of NRENs. These services include security, authentication, Identity Federations, provision of digital certificates, eduroam®, hosting storage, content delivery, IP telephony, video and web-conferencing, repositories, streaming, networked e-Science resources, cloud resources, and e-Learning.

However, the commercial marketplace is developing rapidly with the arrival of many commodity services that provide solutions to some of the users' needs. If individual researchers and institutions sign up to disparate offerings from the many services available, there is a real chance that the vision of an open international collaborative, data infrastructure will be hindered.

The work of the NRENs and large science on grids and clouds and in the Helix-Nebula Project points the way for the future. The community must partner with the commercial sector to build standards-based infrastructures that are integrated with the R&E network architecture in such a way that they meet users' needs and expectations.

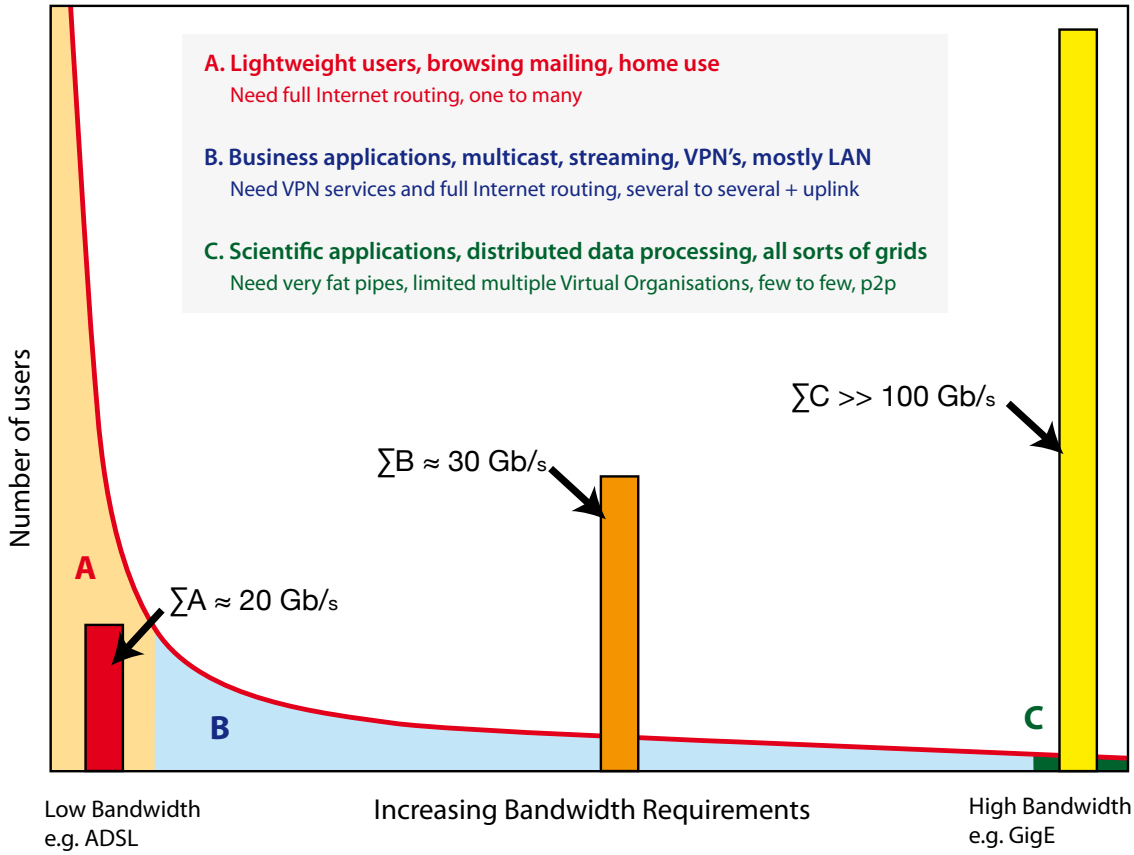
Through their technical, management, and procurement experience, the NRENs, TERENA, and DANTE are well placed to fulfil a brokerage role, acting as a trusted party to aggregate community demand and negotiate with industry to deliver such a service. NRENs should seriously consider whether or not they should provide the commodity services that are easily obtainable in the market.

The Users

It is estimated that GÉANT and the European NRENs connect 40 million researchers and millions more students. This number includes a large body of users with quite modest networking needs. In addition, there is a growing number of important, highly demanding users who require very high bandwidth, minimal transit delay, and zero congestion. These demanding users, many from the e-Infrastructure community, have been mentioned in the ASPIRE Middleware and Data report. It is vital that the network service requirements of these users are well understood and integrated into future network planning.

back to contents page

Cees de Laat of the University of Amsterdam portrayed the distribution of users and their bandwidth requirements succinctly in the following diagram.



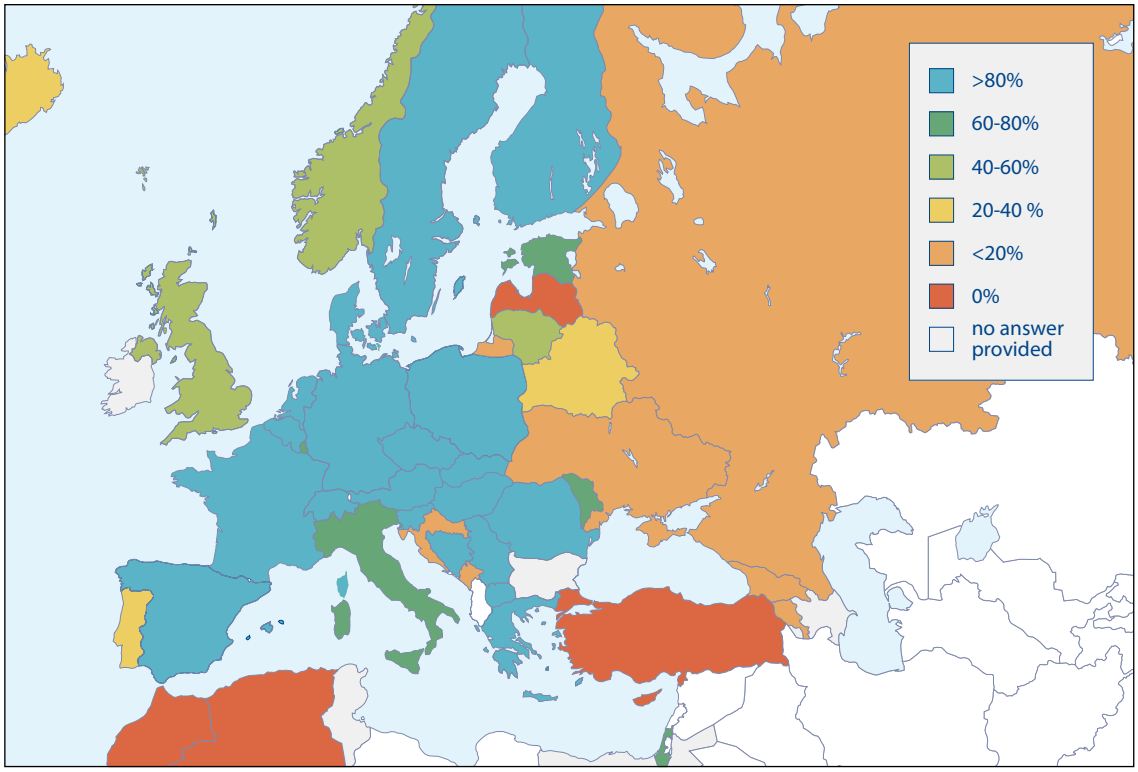
User classes – based on the work of Cees de Laat (UvA)

The question that arises from this distribution of users is how best to serve the needs of such a disparate collection of users on a single, common infrastructure. An approach that has been successfully implemented (e.g., by GÉANT) is hybrid networking, where the many-to-many low-bandwidth users are supported on a classic, fully meshed IP network, while the high-end "Class C" users are provided with switched, end-to-end optical paths that bypass the need for routing in the network core.

European NRENs are increasingly building the network services they deliver to users on underlying, dark-fibre links, either owned by the NREN or obtained on long-term lease. This typically reduces costs per bit for the NREN whilst increasing the NREN's flexibility and agility in delivering new and better services, including hybrid networking. This is a trend that will continue and should be encouraged.

NRENs should aim to support their network services over owned or leased dark-fibre infrastructure in preference to using commercially managed services.

back to contents page



Dark fibres on NREN backbones (2012)[xxiii]

Service Innovation

At the service level, NRENs excel in developing and supporting federated AAI policy and systems. This is discussed at length in the AAI Study, which expresses a vision that "In ten years' time, most research data are readily discoverable and the vast majority of data are electronically and openly accessible. Data are used ethically and according to the norms of the research community, including fair attribution".

The community is well placed to facilitate the development of a common policy and trust framework for identity management that supports Identity Federations, e-Researchers' communities, libraries, and data centres.

Access to e-Infrastructure is a central plank of developing Europe's future capability to participate and compete in the global research arena.

It is vital that GÉANT and the NRENs understand and plan to fully support the demanding users, in particular, members of the e-Infrastructure community.

A second area of development, which will become increasingly important for the community, is that of mobile access. In order to support the increasingly ubiquitous use of mobile devices characterised in the expression, "Bring Your Own Device" (BYOD), NRENs need to collaborate with mobile providers to deliver innovative solutions to the users. To this end, NRENs should collaborate with commercial partners to innovate with new technologies, for example, the integration of LTE and Wi-Fi Services.

back to contents page

Club NREN

The expression "being a member of club NREN" was coined by Klaas Wierenga of CISCO Systems to describe the symbiotic and collaborative nature of the relationship between NRENs and their users. Membership of "club NREN" is largely defined by the NREN status, articles of incorporation, connection polices (CPs), and acceptable use policies (AUPs).

Being outside of "Club NREN" generally means being unable to obtain access to services offered by the NREN. Whilst in the early days of NREN evolution this was the right approach, now that the quest for and creation of knowledge takes place in a much wider constituency, it would be beneficial to widen the remit of who can be included within the "Club's" e-Infrastructure projects, and these groups should be included within the "Club" as a matter of course.

The NRENs should ensure that the e-Infrastructure requirements of this constituency are well understood and integrated into network development and support. Users from such sectors must be enabled to use, indeed encouraged to use, facilities, such as the AAI federations and the services that utilise them (e.g., eduroam®).

The important goal to be achieved is to reduce the current governance complexity.

Expanding the Community

Some European NRENs have been successfully collaborating with Public Service Networks (PSNs) to achieve synergistic benefits. The Connecting Europe Facility (CEF) pan-European high-speed backbone network proposed by the European Commission could offer the opportunity to replicate this success on a pan-European scale.

The CEF is envisaged to provide network connectivity between publicly funded institutions across Europe, adopting a model similar to that of GÉANT and the NRENs. Leverage of the GÉANT and NREN networks could provide synergies to utilise these publically funded networks as a foundation for comprehensive CEF. Safeguards protecting the cutting-edge requirements of the R&E network community would be vital, as would modernisation of terms of references, statutes, CPs, and AUPs.

The convergence of Public Service Networks and the GÉANT/NREN networks should result in a significant advantage for Europe, enabling R&E to benefit from a growth in scale and the public sector to leverage the vast pool of world-class expertise in the NREN community.

It is vital that any shared CEF infrastructure is segmented in such a way that the full requirements of each user community are met or exceeded and that the underlying capacity and performance of the bearer infrastructure are not dictated by the lowest common denominator.

Innovation in Business Models

Historically, NRENs have been, what might be regarded as de-facto monopoly suppliers, meeting most needs of the connected institutions and users. As mentioned in the topic studies, the world is moving forward, and many services traditionally delivered by the NREN are now available as a commodity in the commercial marketplace. The consequence is that NRENs need to achieve a balance between what they will do themselves and what will be done by community or commercial partners.

back to contents page

Whilst commodity providers such as Google, Amazon, Microsoft, and others do approach individual organisations and offer services, there are great gains to be made in coordinating and brokering such arrangements on a national, pan-European, or even global scale. NRENs should be aware that their users are customers of the big aggregators (identity providers – including Google, Facebook, Twitter, and others) so that the community is in a good position to bargain with these suppliers. These bargains might include mandating the use of community federation credentials, performance, privacy, security requirements, or Service Level Agreements.

There are potential risks in working with such providers, so NRENs should include a risk assessment as part of the development of their business models. The risk in not working with such providers is that NRENs could become irrelevant.

Information Dissemination and Community Building

NRENs and their associated organisations have developed a wealth of technical and managerial skills and expertise. Some of these are already disseminated through conferences, workshops and training programmes, and through working collaboratively within TERENA Task Forces and the GÉANT Projects.

Knowledge should be disseminated more widely by increasing the training of networkers and the adoption of staff exchange schemes within the R&E community. This can be leveraged further by using community expertise for an expanded community.

Governance

As can be seen from the breadth of groups and documents consulted by the ASPIRE Project, there are numerous bodies, organisations, and projects that have a legitimate interest in the development of sound strategy and policy for European R&E networking, not least, the users. Any governance model should include an equitable balance of accountability, from the bottom-up influence of users to the top-down requirements of developing and running large, pan-European services.

During the second half of 2012, the Reykjavik Group has worked to put in place the foundations for more streamlined governance of DANTE and TERENA. It is expected that this will be implemented by the end of 2013 and will enable the R&E networking community to respond effectively to the Horizon 2020 programme, due to start in 2014.

Summary

Aspiring to the future means:

- capitalising on the great success of GÉANT and the NRENs;
- collaborating and partnering with commercial players to jointly deliver the services required;
- expanding the use of dark-fibre networks to support the flexibility and agility needed to support all users;
- leading the way on identity federation policy and systems;
- preparing for integrated mass-mobile connectivity;
- expanding the community to include other publicly funded users;
- leveraging the knowledge within R&E networking for the greater good;
- implementing the recommendations of the Reykjavik Group;
- following the recommendations of the four ASPIRE topic reports.

back to contents page

9. CONTRIBUTORS

ASPIRE Clouds Study

Leader: Andres Steijaert, SURFnet, *Netherlands*

ANDRES STEIJAERT works at SURFnet, the national research and education network in the Netherlands. As a member of the SURF Task Force - Cloud, he contributes to the SURF Cloud-first Strategy and supports higher education and research organisations in their joint adoption of the cloud. He directs SURFnet's cloud brokering and vendor management activities. Previously, Andres worked on the development of the SURFconext collaboration infrastructure as Program Manager. Before SURFconext, he coordinated the creation of the SURFnet video streaming platform and SURFgroepen, a centrally hosted collaboration service. As an account advisor, Andres has been in close contact with the IT departments of the Dutch universities to foster their joint efforts on innovative projects to improve the quality of higher education and research.

Brian Boyle, HEAnet, *Ireland*

BRIAN BOYLE is the Network Services Manager of HEAnet, where he works in the Managed Network Services team, developing cost-effective and technically advanced ICT services for national and international networking to benefit the Irish education and research community. Previously, Brian worked as an IP Network Operations Manager in Eircom.net and as an IT Services Developer in Motorola.

Simon Leinen, SWITCH, *Switzerland*

SIMON LEINEN heads the Peta Solutions team at SWITCH, the research and education network for Switzerland. He worked in SWITCH's (backbone) network team for fifteen years. His current interests are centred around ways to make cloud computing useful for research and education.

back to contents page

Ingrid Melve, UNINETT, *Norway*

INGRID MELVE has been Chief Technology Officer with the Norwegian research network, UNINETT since 2006. She leads the eCampus Norway Project, an initiative to create a coherent nation-wide campus infrastructure to support the core process of the higher-education community. With the eCampus programme, she has taken on the challenges surrounding lecture recording, large-scale use of videoconferencing, and mobile solutions. Working for UNINETT since 1994, she became Manager of Applications and Middleware in 1998, and has been involved in the field of identity management since 2000. She holds an MSc in Telecommunications from the Norwegian Institute of Technology.

Yannis Mitsos, GRNET, *Greece*

YANNIS MITSOS is Head of the Network Operations Centre at GRNET, the Greek national research and education network. His main responsibilities are focused on planning, designing, and operating production-grade e-Infrastructures, such as network and cloud services. He is also actively involved in the development of regional network structures in South Eastern Europe.

ASPIRE Mobility Study

Leader: Stefan Winter, RESTENA, *Luxembourg*

STEFAN WINTER is R&D Engineer for the Luxembourg research and education network, RESTENA, where network roaming and identity federations are the focus of his activities. Stefan led the R&D work for eduroam® during the second half of the GN2 Project, and is now continuing these efforts as Roaming Task Leader in GN3. He is also a member of the Global eduroam® Governance Committee.

Amnon Dekel, SHENKAR COLLEGE, *Israel*

AMNON DEKEL is the Chairman of the Software Engineering Department at the Shenkar College of Engineering and Design in Israel. Amnon has over twenty years of experience in product development of IT-based services and applications, as well as more than fifteen years of experience in applied research in the areas of user experience and mobile computing. Amnon is a world expert in indoor navigation with mobile phones. He has received numerous international awards, including a Pulitzer nomination for his work with the New York Times.

Mike Norris, HEANET, *Ireland*

MIKE NORRIS worked in the IT department of University College, Dublin from 1983. As a systems programmer, he had responsibilities for HEAnet, the Irish national research and education network. In 1992, he was seconded to the Higher Education Authority to continue the development of HEAnet. Mike was later seconded to HEAnet when it was incorporated in 1997. In HEAnet, he worked on the expansion and operation of the national network and later on the NREN's wireless strategy. He has taken part in pan-European networking activities, such as GÉANT and the TERENA Compendium. Mike Norris retired in 2012.

Klaas Wierenga, CISCO, *Netherlands*

KLAAS WIERENGA works in the Research and Advanced Development group of Cisco Systems. He worked in the Dutch NREN, SURFnet, for over ten years and currently serves as Chair of the TERENA Task Force on Mobility and Network Middleware. He co-authored the Cisco Press publication "Building the Mobile Internet", and is the inventor of eduroam®. Klaas is particularly interested in future development of the Internet in the areas of identity and mobility.

Maurice van den Akker, SURFnet, *Netherlands*

MAURICE VAN DEN AKKER, as Team Manager Mobility, is responsible for realising the wireless ambitions of SURFnet. Internationally, as Business Development Manager, he is involved in the GN3 mobile connectivity feasibility study. Maurice joined SURFnet in 2002, after being a consultant for data networks within telecom and educational environments for several years. Maurice has a broad educational background in technology and business; he obtained master's degrees in Information Technology, Society and Technology, and in Business.

ASPIRE Data Study

Leader: Rosette Vandenbroucke, Vrije Universiteit Brussel, *Belgium*

ROSETTE VANDENBROUCKE is a computer scientist at the Vrije Universiteit Brussel and represents the university in the Flemish Supercomputer Centre and in the Belgian Computing Grid for Research. During the past several years, she has been active in the e-Infrastructures environment at the international level (EGEE, EGI, e-IRG and several European projects related to e-Infrastructures).

Gill Davies, Royal Conservatoire, *Scotland*

GILL DAVIES is a multimedia producer and consultant and runs her own company, Gill Davies Production Ltd. She has twenty years' experience with the BBC, producing content for radio, web, and TV. As Senior Interactive Development Producer with the BBC Scottish Symphony Orchestra, she was responsible for the orchestra's multimedia strategy. Gill is currently studying part-time for a Master's Research Degree in Collaborative Music Performance over High-speed Research Networks at Edinburgh Napier University.

Antonella Fresa, DC-NET, *Italy*

ANTONELLA FRESA is an ICT expert and was a researcher at Olivetti Pisa, Ivrea, and at the Olivetti Advanced Technology Centre in Cupertino (California). She was Product Manager at Tower Tech., and Project Officer at the European Commission between 1999 and 2002. Since the early 90s, she has been working on European cooperation projects and policy development frameworks. She is Technical Coordinator of several EC projects: FP7-ICT, FP7-e-Infrastructures, CIP Pilot B, CIP BPN. Her personal interest and the focus of her current research are related to e-Infrastructures for digital cultural heritage.

Jens Jensen, STFC, *United Kingdom*

JENS JENSEN received his PhD in Maths from the University of Aarhus, Denmark. He currently works for the Science and Technology Facilities Council, one of seven UK research councils, where he is Head of the Data Services Group in e-Science. He leads the grid storage and data management group in GridPP, the UK grid for particle physics. He is Area Director for security in the Open Grid Forum (OGF), and a member of the OGF standards council. He leads the security work package in the EU-funded Contrail Project, a project building federated cloud services for, among others, life sciences and high-performance scientific data processing. He is the CA Manager for the UK e-Science certification authority, and occasionally does work for the national grid service. Most of his work is in data security, data management, and identity management infrastructures. In the past, he has also done work in maths, quantum information theory, quantum cryptography, and various aspects of e-Science.

Andrew Lyall, EBI, *United Kingdom*

ANDREW LYALL is the ELIXIR Project Manager. The purpose of ELIXIR is to build a sustainable infrastructure for biological information in Europe. Before this, Andrew worked in the pharmaceutical and biotechnology industries. He has a PhD in Bioinformatics and a long-standing interest in handling and analysing large datasets.

Roshene McCool, SKA, *United Kingdom*

ROSHENE MCCOOL is the Element System Engineer for Signal Transport and Networks for the SKA (Square Kilometre Array). She has eighteen years' experience in the field of optical transmission. Roshene joined the SKA organisation in 2009. As well as her role as a specialist in the field of signal transport, she supports the system engineering for the SKA and has a management role in the coordination of work packages for the development of solutions in the domain of signal transport and networks for the SKA. Roshene is a chartered member of the Institution of Engineering and Technology (IET).

ASPIRE NRENs Study

Leader: Michael Nowlan, *Ireland*

MICHAEL NOWLAN is a consultant in the higher education networking and IT sector, especially in a European context. Until 2008, he was Director of Information Systems Services at Trinity College Dublin and was involved with HEAnet, the Irish NREN, since its foundation in 1983.

David Foster, IHC/CERN, *Switzerland*

DAVID FOSTER has both a BSc and PhD from Durham University, Department of Applied Physics and Electronics and an MBA from Durham University Business School. He has spent more than thirty years at CERN and has held many technical and managerial roles. He currently chairs a number of international committees on networking and supercomputing as well as representing CERN on a number of projects with the European Commission. David is currently Deputy IT Department Head at CERN and has particular responsibility for international network strategy as well as infrastructure strategy in the areas of information management. He is a Fellow of the Institute of Physics and a member of the Chartered Management Institute and the Association of MBAs.

Victor Reijs, HEANET, *Ireland*

After studying at the University of Twente in the Netherlands, VICTOR REIJS worked for KPN Telecom Research and SURFnet. He was involved in CLNS/TuBA (one of the earlier alternatives for IPv6). Experience was gained with x.25 and ATM in a national and international environment. His last activity at SURFnet was the tender for SURFnet5 (a step towards optical networking). Having emigrated to Ireland, he manages the network development team of HEAnet and is actively involved in international activities, such as GN3 and Mantychore (IP Networks as a Service), as well as (optical) networking, point-to-point links, virtualisation and monitoring.

Asher Rotkop, IUCC, *Israel*

ASHER ROTKOP is Director General of IUCC, CIO of Tel Aviv University, and Deputy Director General for Higher Education. He is an IT expert, with wide experience in the IT Infrastructures and Information Systems of universities. He is focused on leading IUCC (the NREN of Israel) towards fulfilling the universities' needs by expanding its range of activities to include added-value services, such as cloud and DRP, database agreements with libraries, and inter-university IT services.

Christoph Witzig, SWITCH, *Switzerland*

CHRISTOPH WITZIG is the Head of the Central ICT Providers at SWITCH, the NREN of Switzerland. He holds a degree in High Energy Physics from ETH Zurich and worked for several years at Brookhaven National Laboratory in Upton, NY. He held various positions in the commercial sector before joining SWITCH in spring 2005.

ASPIRE Students

Julius Kriukas, Kaunas University of Technology, *Lithuania*

JULIUS KRIUKAS is currently studying for PhD in Computer Science at Kaunas University of Technology. He is also working as an engineer at LITNET, responsible for optical backbone transmissions and IPv6 deployment. Julius is interested in cryptography, IPv6, and open source development.

Anton Karneliuk, OpCo - FE Velcom, *Austria*

ANTON KARNELIUK is Master of Technical Science (topic - system of resources' management in virtual networks). He is a member of transport network planning department in OpCo - FE Velcom (a member of Telekom Austria Group).

TERENA ASPIRE Team

John Dyer, TERENA

JOHN DYER is the Business and Technology Strategist at the Trans-European Research and Education Networking Association (TERENA). He is responsible for supporting strategic planning activities at TERENA. He studied the Physical Sciences, undertook research on sensors for clinical use, and in 2001 successfully completed an MBA.

Magda Haver, TERENA

MAGDA HAVER joined TERENA in January 2011 as a project assistant and has worked on the ASPIRE Project and with the GÉANT Project's Partner Services Promotion team. Magda's background is in communications, event planning and conference organisation, in both academia and with commercial companies.

10. GLOSSARY

3G	3rd Generation (mobile telecommunications technology)
4G	4th Generation (mobile telecommunications technology)
AAI	Authentication and Authorisation Infrastructure
API	Application Programming Interface
ASPIRE	A Study on the Prospects of the Internet for Research and Education
AUP	Acceptable Use Policy
BMS	Biological and Medical Sciences
BYOD	Bring Your Own Device
CA	Certification Authority
CEF	Connecting Europe Facility
CERN	European Organisation for Nuclear Research
CIO	Chief Information Officer
CP	Connection Policy
CRM	Customer Relations Management
DANTE	Delivery of Advanced Network Technology to Europe
DC-NET	Digital Cultural heritage NETwork
DRP	Disaster Recovery Planning
DSI	Digital Service Infrastructure
eduGAIN	Education GÉANT Authorisation Infrastructure
eduroam	Education Roaming
EGEE	Enabling Grids for E-Science
EGI	European Grid Infrastructure
e-IRG	e-Infrastructure Reflection Group
ELIXIR	A sustainable infrastructure for biological information in Europe
ERA	European Research Area
ERIC	Community legal framework for a European Research Infrastructure
ESFRI	European Strategy Forum on Research Infrastructures
EU	European Union
GA	General Assembly
Gbps	Gigabits per second
GÉANT	Gigabit European Academic Network Technology
GHG	Greenhouse Gas

back to contents page

GN3	Multi-Gigabit European Academic Network project
GPP	Green Public Purchasing
GPS	Global Positioning System
HE	Higher Education
HPC	High Performance Computing
ICT	Information and Communication Technologies
IdP	Identity Provider
IET	Institution of Engineering and Technology
IETF	Internet Engineering Task Force
IGTF	International Grid Trust Federation
IP	Internet Protocol
IP	Intellectual Property
IRG	e-Infrastructure Reflection Group
ISP	Internet Service Provider
K-12 schools	primary and secondary schools (in the US)
LAN	Local Area Network
LHC	Large Hadron Collider
LTE	Long Term Evolution – a standard for wireless communication of high-speed data
NREN	National Research and Education Network (can also refer to the operator of such a network)
OGF	Open Grid Forum
PPP	Public-Private Partnership
PSN	Public Service Network
PUE	Power Usage Efficiency
R&E	Research and Education
REFED	Research and Education Federation
RI	Research Infrastructure
RTD	Research and Technology Development
SDI	Scientific Data Infrastructure
SERENATE	Study into European Research and Education Networking As Targeted by eEurope
SKA	Square Kilometre Array
SME	Small- and Medium-Sized Enterprise
SOA	Service-Oriented Architecture
TERENA	Trans-European Research and Education Networking Association
U.S. UCAN	United States Unified Community Anchor Network
VLAN	Virtual Local Area Network
VRF	Virtual Routing and Forwarding
WAN	Wide Area Network
Wi-Fi	Wireless exchange of data
WiMAX	Worldwide Interoperability for Microwave Access

back to contents page

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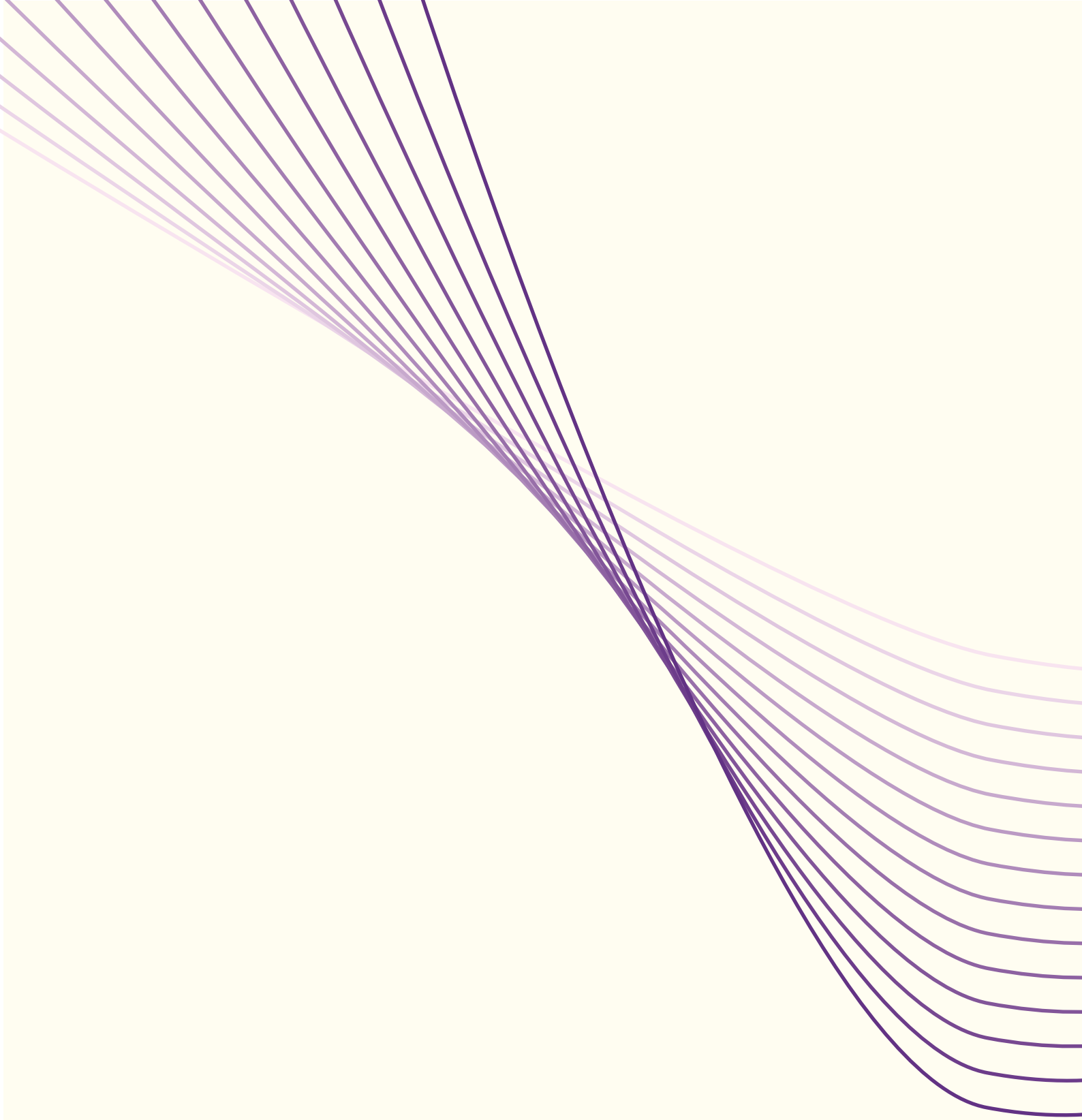
back to contents page



For further information please contact:

TERENA Secretariat
Singel 468 D
1017 AW Amsterdam
The Netherlands

t. +31 20 530 44 88
f. +31 20 530 44 99
secretariat@terena.org
www.terena.org

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