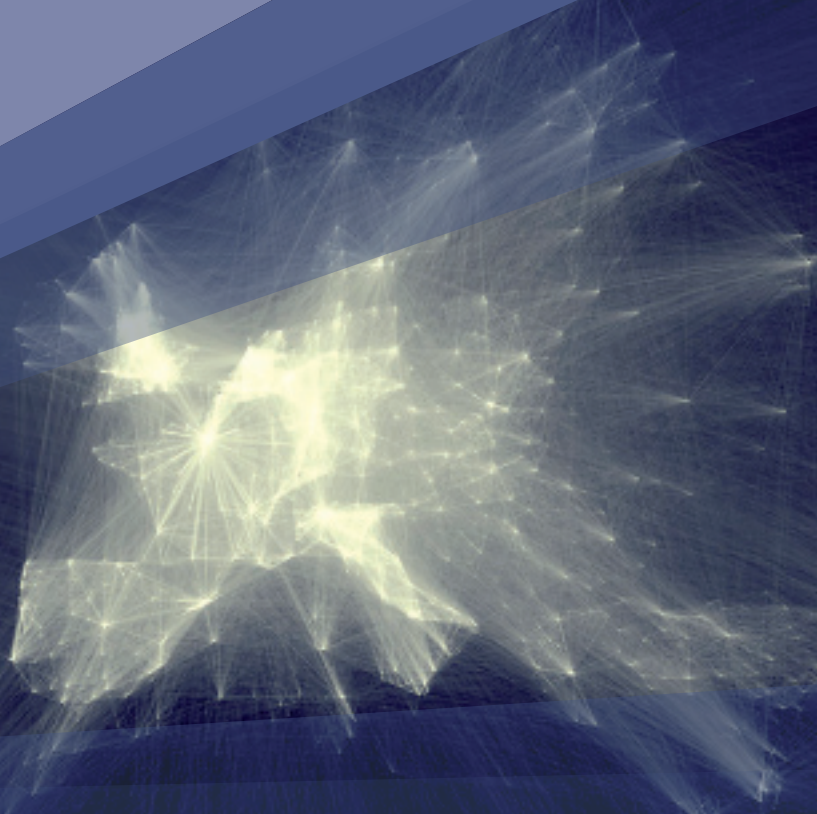


Knowledge without Borders

GÉANT 2020 as the
European Communications Commons



Report of the GÉANT Expert Group
... **October 2011**



European Commission
Information Society and Media

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Foreword

The Digital Agenda for Europe aims to develop a flourishing digital economy by 2020, with everyone able to reap the benefits of the digital revolution. In particular, research and innovation are



essential if we are to deliver smart growth and jobs.

The quality and efficiency of scientific research today depends on ICT infrastructure. Researchers are increasingly working in large teams, with research collaborations sometimes spanning

the entire world. In that context, access to high speed communication networks is itself a powerful scientific instrument.

Through the joined force of the national research and education networks, GÉANT has made it possible for scientists across Europe and the world to work together, in real time, on ground-breaking research. Bridging digital and geographical divides, it has given 40 million researchers and students in 40 European countries access to the processing power needed to share massive volumes of data: data which is essential whether you are studying the smallest known particles, finding a cure for epilepsy or setting up a typhoon early warning system. With fast evolving technology, services and capacity, GÉANT remains the most advanced research network in the world.

The European Commission has provided consistent support to GÉANT over the past decade. We are committed to promoting worldwide research collaboration to tackle problems from medicine to climate change and beyond. The power and scope of GÉANT ensure Europe remains a central hub for research and education, offering the best infrastructure to the brightest minds in the world.

Rich with these successes, GÉANT must now position itself to face the challenges of the next decade such as the upcoming "data deluge", connectivity at world scale, and providing a seamless service to all EU scientists to build an online European Research Area. This is why the Commission has asked a group of high-level experts to advise on future actions.

I am certain that this report will be an invaluable input for formulating research, innovation and e-infrastructure policies not only in the Commission but also in the Member States and GÉANT community. I invite every organisation and every citizen involved in research and education to take note of this report and to use it when discussing and prioritising research and investment.

Neelie Kroes

**European Commission Vice-President
for the Digital Agenda**

GÉANT:

The Journey Continues

In 1984 I was freelancing as the editor of a micro-computer magazine and travelled to a computer fair in London. At the time citizens of Yugoslavia had to pay a substantial deposit to travel abroad, which really made us angry. On the long journey by train the co-editor and I played with an idea to get some modems, use them to get the data across the border, process data locally and then export the results back to



the West, bypassing the monitoring eye of the customs officials and avoiding the business-hostile policies of that Orwellian country.

Ten years later, in 1994, I was doing exactly that: I created a search engine for free software, indexing the FTP sites on which it

resided and serving the data on the web. What made this possible was that since 1991 the internet had been available in Slovenia, thanks to the European academic networking and Arnes, the Slovenian National Research and Education Network. For a period in the mid-1990s this free service was generating about a third of all Slovenia's outbound internet traffic; it later evolved into shareware.com.

Another ten years on, in 2004, Slovenia joined the European Union. Not only bits and bytes could flow freely across the border, goods, capital and people could too. In the meantime, academic networks allowed me to put Slovenian construction informatics on the global research map, to publish one of the first open access

scientific journals on the Web, and to collaborate on European and global research and education projects.

I, like thousands of academics across Europe, have benefited hugely from GÉANT and its predecessors. Over the last 10 years GÉANT, the pan-European communications infrastructure serving a collection of national research networks, enabled networking and collaboration of the European Research and Education Community. Moreover, in the words of Neelie Kroes, by *"bringing together the brightest minds in the world, GÉANT not only benefits Europe's competitiveness, but is also boosting collaboration between researchers on a global scale"*.

After 10 years, the future role of GÉANT needed to be re-evaluated. In 2010, the European Commission set up a GÉANT Expert Group with the mission to *"articulate a 2020 vision for European Research and Education networking and identify an action plan for realizing this vision"*.

This document presents this vision and lists a number of recommendations to European and national policy-makers, networks, CIOs of various levels and other stakeholders.

It is based on the understanding that the current economy is a competition of and for talent. Richard Florida correctly argued that talent is attracted by tolerance, technology and other talent. The three T-s attracted talent to great centres of knowledge and learning in the past: for example to the teachers at the Academy of Plato and Lyceum of Aristotle, to the Library of Alexandria, to the University of Bologna, or to the instruments of the Greenwich Observatory.

Today, the infrastructure that attracts is less and less material - lecture rooms, libraries or instruments - but increasingly digital. Attraction does not imply physical movement. The infrastructure that matters – one that puts you at the centre of the scientific community – is predominantly the e-infrastructure.

GÉANT has been a vital element of this infrastructure up to now. To continue leading in the world and remain at the forefront of the scientific and social developments, to achieve the Europe 2020 goals, Europe must step up its ambition and efforts to provide its talent with the best possible digital infrastructure. GÉANT2020 is our vision for the European networks achieving this. National governments and the European Institutions must see this as a vital policy goal.

This is the message of the Expert Group.

I would like to thank its members: Arndt Bode, Vasilis Maglaris, Dorte Olesen, Roberto Saracco, Peter Tindemans and Pedro Veiga for the expertise, effort, and passion with which they contributed to the report. Further, my appreciation goes to our rapporteur Mike Sharpe for shaping the Group's ideas into a coherent document; to all of our almost 30 invited experts for their contributions; and finally to the officials of the Commission - Mário Campolargo, Kostas Glinos and Jean-Luc Dorel – for their dedicated support.



Žiga Turk, Chairman

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GÉANT 2020:

Key Findings of the GÉANT Expert Group

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. Ideas are created and communicated using digital technology. In this digital and highly interconnected world, knowledge, innovation and learning flow readily, unconstrained by the distances and boundaries of former times. Innovation and creativity are the sources of competitive advantage. Europe must embrace growth through knowledge by empowering the talent – whether a scientist, academic, student, entrepreneur, artist or citizen – and stimulate the emergence of new paradigms of innovation and creativity.

The creative society needs infrastructure. Just as the traditional economy and society have physical and organizational infrastructures, this new society requires common infrastructures for ideas to flow freely and for empowering people with ideas. Having a first rate infrastructure is essential in being able to explore first rate ideas. At the core of the creative society is research and education (R&E).

The European Research Area is the organizational infrastructure for research and innovation. Knowledge is the result of people collaborating. Ideally all knowledge and tools should be at researchers' fingertips allowing independent and cooperative work. In emphasizing the European Research Area (ERA) as a key policy objective, Europe has enshrined the so-called "fifth freedom" – the free circulation of researchers, information and technology – as a building block that supports the free movement of knowledge. In the ERA all players should benefit from attractive

conditions for carrying out research and investing in research-intensive sectors in Europe; as well as healthy Europe-wide scientific competition, together with the appropriate level of cooperation and coordination.

GÉANT is the communication infrastructure backbone to Europe's research and education community. Funded in part by the EU and developed progressively over the last 20 years, the European R&E networks have performed well and have notable achievements. They are world leaders in many areas; an innovation environment and ideas generator, helping to drive the development of new networking technologies and services. Connecting 40 countries and reaching tens of millions of users in Europe, GÉANT has become not just an infrastructure for e-science but an *in-silico* realization of European integration.

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. Globalisation continues a pace, especially in science where the share of scientific outputs from the emerging economies is growing rapidly. Knowledge and openness to new ideas will be essential in tackling major societal challenges such as climate change, resource scarcity, and demographic shifts.

The nature of the scientific process is changing fundamentally, with research becoming more interdisciplinary and data driven. Big Science projects, which were once confined to a few communities such as high-energy physics, are now found in virtually

every scientific discipline, including social sciences. Such projects routinely present the most challenging requirements for the research networks. Scientists rely increasingly on trustworthy networks to navigate the complex web of people, data and resources.

Knowledge is increasingly being created outside traditional research organizations. Teaching and learning are happening outside of conventional educational and training settings and span the lifetime of people and enterprises. Today's knowledge workers are increasingly mobile, meaning that Europe has to compete for the best talents worldwide, in science, business, industry and public administration.

Digital technologies are changing the nature and context of innovation across the economy. Open innovation and open learning are two increasingly interesting paradigms. The research networks tend to be at the most innovative end of the spectrum, and new technologies and services are often discovered in academia where the early adopters are most frequent. The networks provide European industry with a testbed for advanced hardware, software and applications, while also offering an increasingly important market for the supply of advanced technology and services.

Technology is evolving fast and Moore's law is holding. Unlimited bandwidth is opening the way to new networking applications, while developments such as fibre and advanced mobile will bring the always-on everywhere vision closer to reality. Major resources such as high-performance computing, data repositories, and data visualisation are increasingly being virtualised. Everything – people, devices and sensors – are connected, extending the digital landscape.

The situation is critical and Europe risks losing out. Past achievements are no guarantee of future success and Europe faces stiff competition. Other regions, including the United States and China, are investing heavily in research networks as a source of competitive advantage, putting Europe's innovation efforts in a stark light. It is time to reassess the requirements and renew the European networks as a key 21st century infrastructure.

A Vision to maintain Europe's lead:

"GÉANT 2020" is the European communications commons, where talent anywhere is able to collaborate with their 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 Support knowledge communities by providing world-class connectivity and services.
- 2 Support the growth of these communities, in both breadth and depth within Europe, and opening up to talent beyond Europe's borders ;
- 3 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 Reorganize to cope with the constantly changing environment.

Goal 1: Support Knowledge Communities

The main mission of GÉANT 2020 is to support knowledge communities. The GÉANT infrastructure will be a genuine commons, with its core business being to serve Europe's research and higher education. It will 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 will address the needs of both advanced high-end users operating at the leading edge, and less information-intensive communities requiring commodity services. In terms of activities, provision of connectivity, identity and trust are the lowest common denominator.

Integrate the work of knowledge communities.

Each such community is unified by a common learning, research or some other interest. The digital aspect of this unification would be the ICT services that can be combined or integrated to support this goal. Users take connectivity for granted; GÉANT 2020 needs to provide services beyond what is available from the market to remain relevant.

Embrace the services culture. A focus on users with differentiated needs and demands calls for major cultural change. The networks must embrace the service culture, putting users and their requirements at the centre stage. The current generation networks must evolve into service-enabled infrastructures that provide a platform for innovation by users. This service provision spans, and requires interaction across, three levels: advanced networking R&D, testbeds, and production services. It is the co-existence of these three levels, in unique combination, that constitutes a European communications commons and distinguishes the research and education networks from commercial service provision.

Develop a clearer business orientation. National Research & Education Networks (NRENs) should be encouraged to make explicit business decisions on which services to offer and how they are to be delivered. Their focus should be on those services not available from commercial providers and on stimulating market innovation; this could be achieved either through centralized provision and/or through

competition. In addition, a service culture requires a more responsive and customer-focused approach by the NRENs, through investing in support services and skills.

Think of the weakest link. The GÉANT infrastructure needs to be looked at as a chain, running from desk to desk and to servers. Governments and institutions therefore must be responsible for adequate investments in each mile and metre. NRENs will have to work much more closely with campus and other local networks to ensure that users benefit from infrastructure of the highest quality and that solutions for true multi-domain networking are found (for example in the area of security).

Goal 2: Expand Knowledge Communities

As society is increasingly creative, knowledge will be created, needed and communicated at unusual places, both within Europe as well as beyond the borders of Europe.

Open the organizational walls. Research and education no longer take place only behind the walls of traditional organizations. Scientist, researcher, entrepreneur and citizen should be in a position to access data and resources regardless of location, be it at home, roaming in another country or at another institution, or on the road. A paradigm of openness should prevail: as in open access to scientific data, open publications, open courseware. Software developments using public funds within the evolution of GÉANT 2020 should be put under an open source license.

Bridge Europe's digital divides. Talent in Europe is distributed equally; opportunities that this talent is offered are not. GÉANT 2020 should strive to eliminate inequalities due to state, geographical location, income, etc. Solidarity has to be the principle in bridging the geographic divide.

Open up European science to the world. Science is more and more a global endeavour. Success for Europe as a global scientific hub requires that GÉANT 2020 should remain active in providing links to all

other continents; active in offering the most advanced networking services; and active in serving all major international research projects. For maximum leverage, Europe must also 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.

Extend beyond the traditional uses in research and education into wider public services. Leveraging the scale and capacity for innovation, the networks can be key drivers of public sector change, enabling service delivery and partnerships. By aggregating smart users, the European networks can help drive innovation in public sector service provision, assist in reducing the costs of public services and improving the user satisfaction.

Goal 3: Push the State of the Art

A platform for innovation: A much stronger orientation towards innovation is required, building on the networks' unique, but underutilized, position within the European innovation ecosystem. Innovation here means not just (or even primarily) technological innovation but also in the use of technology and in the provision of services. NRENs should become living labs, providing live testbeds for future technologies and connecting researchers and others to the market. No commercial provider has this capability and it is a further demonstration of GÉANT's European scale.

Organize for innovation. To realise this goal, innovation has to be made a central focus of networking activities, and supported/reinforced through appropriate structures and funding. Greater inclusiveness and transparency must be introduced, opening these activities up to industry, academia and user communities.

Provide a research partner and lead customer for the European ICT industry. NRENs should play a key role in mediating between the higher education sector and its suppliers in the provision of commercial networking services, including cloud services. Advanced networking testbeds should be available in all industry sectors and academia. GÉANT 2020 including NRENs, DANTE and funding agencies should

use pre-commercial procurement to foster innovation in technology and services within European industry.

Work more closely with the industry in the area of service provision. The provision of services will see a much closer involvement of telecom providers and industry at large. GÉANT 2020, particularly the NRENs and DANTE should be encouraged to make explicit business decisions on which services to offer and how they are to be delivered. There will increasingly be more commercial services available for meeting demands of researchers. GÉANT 2020 and NRENs should use them when the requirements of functionality, service guarantees, costs and trust allow. In all cases the benchmark should be whether the GÉANT 2020 can add value over what is available commercially, for example through coordination, market aggregation, resource sharing or sharing of best practice.

Goal 4: Reorganize for Change

Systems, procedures and structures designed for the previous era are not necessarily those best suited for 2020. Organizational set-ups, business models, governance structures, funding regimes, regulation: all must be adapted and updated and where necessary new ones put in place. The vision requires that we reappraise the role of the European networks and set a course to equip them for addressing three core functions: (1) community building, high level strategy and coordination; (2) connectivity & service provision; and (3) innovation.

Structure the governance of the European Communications Commons for accountability and transparency. Distinguish between advisory, supervisory and executive functions in organizations with well defined and non-overlapping responsibilities and representations; ensure a stronger role for users; find appropriate mechanisms to involve international communities and projects; adopt a flexible, open and competitive approach to European and global connectivity; strive for a leading European role in global coordination and standardisation forums. Proposals should come from NRENs and their European-level organizations. In addition, NRENs may wish to form open and non-exclusive clusters to meet some of their demands.

Focus operations on technical flexibility and services for users. Guarantee the best international connectivity and continue the hybrid approach including IPv6 services for the majority with trust, security and privacy centre-stage. Ensure multi-domain performance; embrace mobile solutions; promote virtualisation and support experimental testbeds for Future Internet research and innovation.

Ensure a stable and sustainable funding regime. Overall, a step-change is required in Europe's public investment in e-infrastructure in general, and the research networks in particular. Core backbone services to sustain the European Communications Commons should be fully funded by the EU with a check on quality and needs, and EU support should be concentrated in the Research and Innovation Framework Programme. Member States should continue to invest in their research and education networks and in campus level resources to bring the full benefit to users. Nationally, user institutions should share in the costs of networking, increasingly on a competitive basis for services. High-end users and research infrastructures should budget for networking services. Innovation should be funded by EU, Member States and industry on a project basis. Innovative use of Structural Funds

and the Risk Sharing Financial Facility can further help address digital divide issues and investments in networks.

The European networks should fully participate in supporting global collaborations. This should focus both on developed nations, epitomized by the USA, and emerging and developing nations. The BRIC countries and Africa, in the latter case with support of EU's development aid, are priorities for Europe on the world stage.

Align the regulatory frameworks in Europe to NRENs' potential. A coherent European view on regulation may make more public services benefit from the networks than just their research and education core users. Costs of data roaming must be cut to enable GÉANT to be much more active in the wireless domain. As a stimulus to innovation, including leveraging scientific data from billions of sensors, reserve spectrum for the exclusive use of the research community. Reflect the principle of a European Communications Commons for knowledge, innovation and learning in any legislation, especially regarding mobility, on the European Research Area.

1 European Research Networks: Past Successes and Future Potential

1.1 GÉANT: a Key Resource for European Research

Dr. Marcin Gawroński is looking for planets, and breaking records in the process. Leading a team of scientists at the Torun Centre for Astronomy, Nicolaus Copernicus University in Poland, Dr. Gawroński is using a technique called electronic Very Long Baseline Interferometry (e-VLBI) to observe red dwarfs, looking for patterns that would indicate the orbits of companion planets. His first e-VLBI observation of these sources was carried out in March 2011 using the European VLBI Network (EVN) and was the longest e-VLBI observation carried out by the EVN.

This observation used Torun's own 32-metre telescope in conjunction with other radio telescopes spanning 2100 kilometres across the width and breadth of Europe. Each telescope streamed the data to the central processor at the Joint Institute for VLBI in Europe (JIVE) in the Netherlands, generally at 1 Gigabit per second (Gbps), for a steady total throughput of about 7.5 Gbps for most of the 48 hours of observation.

Due to the real-time element of e-VLBI, the data was available considerably sooner than would have been the case with traditional EVN observations. With traditional VLBI, data is recorded onto hard disks at the telescopes and shipped to the data processor for correlation at a later time. More importantly, however, Dr. Gawroński notes, "e-VLBI with the EVN is the best tool for astrometric studies of young, active red dwarfs. The flexibility in scheduling observations is crucial for measuring orbital periods outside of our own solar system, and the EVN's sensitivity is unsurpassed."

The work undertaken by Marcin Gawroński and his colleagues is made possible in part by GÉANT, a high-speed network that supports European scientists and researchers. First established around twenty years ago, GÉANT has evolved into a fast and reliable pan-European communications infrastructure serving Europe's research and education community. With fast-evolving technology, services and capacity, GÉANT enables the best minds across Europe and the world to work together on ground-breaking research activities that were previously not possible. Dedicated communications networks now form the basis for advances in many areas of science, in both applied and curiosity-driven research.

These vital networks are supported by a community of national research and education network (NREN) partners in 40 countries. NRENs are national organisations that support and service the research and education networks in their territories. They aim to provide top quality network services for their national communities, although vary considerably in their scope, activities and funding. Interconnectivity, within Europe and globally, is provided by successive generations of backbone (now known as GÉANT), and increasingly by other types of connections as well.

The NRENs are complemented by a number of other organisations and structures, which together make up the European networking landscape (see Box 1). These include: DANTE, a not-for-profit company owned by a number of NRENs that has built and operates the GÉANT backbone; the NREN Policy Committee (NREN PC), which oversees governance of the networks; and TERENA, a forum for networking and collaboration within the NREN community.

Box 1: Who's Who in European Research Networking?

A quick guide to the alphabet soup of European research and education networks:

DANTE (www.dante.net): (standing for 'Delivery of Advanced Network Technology to Europe') is a limited liability company and a not-for-profit organisation that plans, builds and operates advanced networks for research and education. It is owned by fifteen European NRENs and works in partnership with them and in cooperation with the European Commission.

eIRG (www.e-irg.eu): The e-Infrastructure Reflection Group is a policy forum set up by the European Commission to define and recommend best practices for the pan-European electronic infrastructure efforts. Its mission is to pave the way towards a general-purpose European e-Infrastructure.

GÉANT (www.geant.net): is the pan-European communications infrastructure serving Europe's research and education community. The current network and associated programme of activities, known as GN3 is co-funded by the European Commission and the NRENs, with total EC funding of €93 million and €88 million from NRENs over four years from April 2009.

NRENs: National Research and Education Networks are national institutions in the EU member states and associated states responsible for providing research and education networking services within their territories. 32 NRENs representing 36 countries are full members of the NREN PC and 4 are special members. Further information on NRENs' capabilities and activities can be found in the annual publication *TERENA Compendium of National Research and Education Networks In Europe*, www.terena.eu/compendium.

NREN PC: The governance body of the GÉANT backbone consisting of senior representatives of participating NRENs, DANTE and TERENA as well as 4 observers.

TERENA (www.terena.eu): Trans-European Research and Education Networking Association offers a forum to collaborate, innovate and share knowledge in order to foster the development of internet technology, infrastructure and services to be used by the research and education community.

In this report we use the terms 'the European network' or 'European networking' as a shorthand for the European research and education networking community **as a whole**: that is as the sum of the GÉANT high-speed backbone, other international connections, the NRENs across Europe, and the user communities that are an increasingly important feature of the research networking environment. Further, we use the term **GÉANT 2020** to refer to the future concept of the networks, i.e. to the vision, structure, organisation and activities within the 2020 timeframe specified under the Group's mandate.

Two decades of achievements

Since 1991 Europe has built six generations of networking infrastructure, each faster and more reliable than the previous. Development has followed an evolutionary approach, with attention slowly shifting away from raw connectivity while starting to build links to other world regions. So far Europe has sustained its investments in research networks.

Established a world leading position: In the 1990s Europe lagged behind North America in its research networking capabilities. This period was characterised by extremely high prices due to telecommunications monopolies, limited offer of services especially in peripheral regions of Europe, and rapid technological change related to growth of network capacities. Since liberalization in the telecom sector, major investments at national and European levels as well as extensive European collaboration have allowed Europe to catch up. It is now a world leader not just in terms of connectivity but also in other aspects of research networking, such as innovation and services.

An innovation environment and ideas generator: Many new ideas have come from Europe over the last 20 years. A high-speed hybrid dark-fibre infrastructure enabling stable IP services as well as advanced light path services in a complex multi-domain environment has become the basis for networking everywhere. Europe was a key driver in the development of Eduroam, a secure roaming access service developed for the research and education community that is now being adopted worldwide by this community. Eduroam allows students, researchers and staff from participating institutions to obtain internet connectivity across campus and

when visiting other participating institutions by simply opening their laptop. European networks were early adopters of IPv6, a networking protocol that provides a solution for the shortage of internet addresses, deploying and testing this new protocol at a large scale since 2003, in cooperation with industry.

European dimension: GÉANT has a strong European dimension. Connecting 40 countries and reaching several tens of millions of users in Europe, it has become not just an infrastructure for e-science but an instrument of European integration. GÉANT is an essential feature of the European research landscape and brings particular benefits for small/peripheral countries, allowing them to leverage European research and participate in major science projects and initiatives such as those at CERN and JIVE.

The European networking community's impact is felt well beyond research. For instance, it has been a major player in coordinating Computer Emergency Response Teams (CERTs), public sector organisations that act in response to computer security incidents and provide advice to reduce the threat exposure.

Facilitating global infrastructure: GÉANT's reach extends to countries beyond Europe, through interconnections with other research and education networks across the world. Today, Europe sits at the heart of global research networking, and indeed the GÉANT community has played a pioneering role in facilitating many of the international networks and links among them (see inside back cover). These international connections are a key feature and a substantial achievement in their own right.

GÉANT utilises a flexible, hybrid network architecture. From a technical point of view, GÉANT makes different technologies interoperable. Its open policies and adherence to net neutrality principles have allowed it to source the most appropriate technologies for its needs, while at the same time helping to drive innovation in European industry. GÉANT was the first 'hybrid' network deployed on an international scale, using an innovative combination of routed IP and switched infrastructure, and delivering leading-edge standards of reliability (see Box 2). The network design for GÉANT focuses on maximising operational and service flexibility.

Box 2: The GÉANT Architecture

The GÉANT backbone comprises an innovative, hybrid network architecture delivering a flexible, robust service to NRENs' users with choice of connectivity options spanning IP (v4 and v6) and point-to-point circuits. This has involved the installation of 50,000 km of network infrastructure, including 12,000 km of optical fibre across Europe. Over 80% of users across the GÉANT service area are able to access to point-to-point circuits at up to 10 Gbps dedicated capacity. Total NREN partner access capacity to the network has increased more than 800% since 2000, from 32 Gbps to 258 Gbps.

All networks send information by splitting the data into packets (datagrams or chunks) and routing or switching these across the paths in the network. As a hybrid network, GÉANT offers unprecedented flexibility in how the packets are managed. It is made up of a general purpose research internet carrying multiple users' traffic, and virtual "private" network paths dedicated to carrying the traffic of individual projects that have particular requirements relating to aspects such as quantity, security or accuracy of the data transfer. The aim is to meet the needs of different types of user with the most appropriate technology. Combining the two transmission methods in one network is innovative and opens up new service possibilities. GÉANT has led the world in deploying this hybrid technology in a production network on an international scale.

Eighteen of the EU/EFTA NRENs currently offer dedicated wavelengths (lambdas) to their customers, and another is planning to do so. In addition, at the pan-European level the GÉANT lambda service provides private, transparent 10 Gbps wavelengths between any two NRENs connected to the GÉANT dark fibre cloud. In most cases, the number of lambdas is increasing, however overall the numbers are still low.

Not all international connectivity is via the GÉANT backbone. In addition to GÉANT connections, NRENs obtain international connectivity through cross-border links (between institutions, or from NRENs to institutions), NREN-to-NREN connections, interregional backbone providers (such as Nordunet), and connections from NRENs to other continents or

to commercial operators (Figure 1). Also a number of NRENs operate or have strong cooperation with major internet exchanges (IXs) in Europe and worldwide. As NRENs take care of more international connectivity themselves, some are questioning whether it is necessary any longer to maintain expensive GÉANT backbone Points of Presence in all countries.

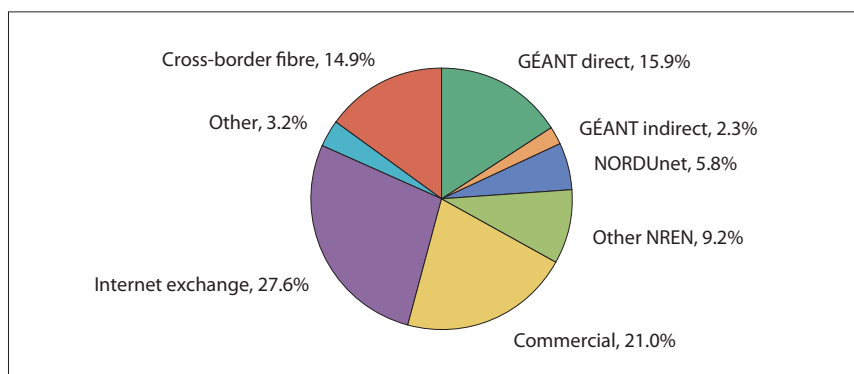


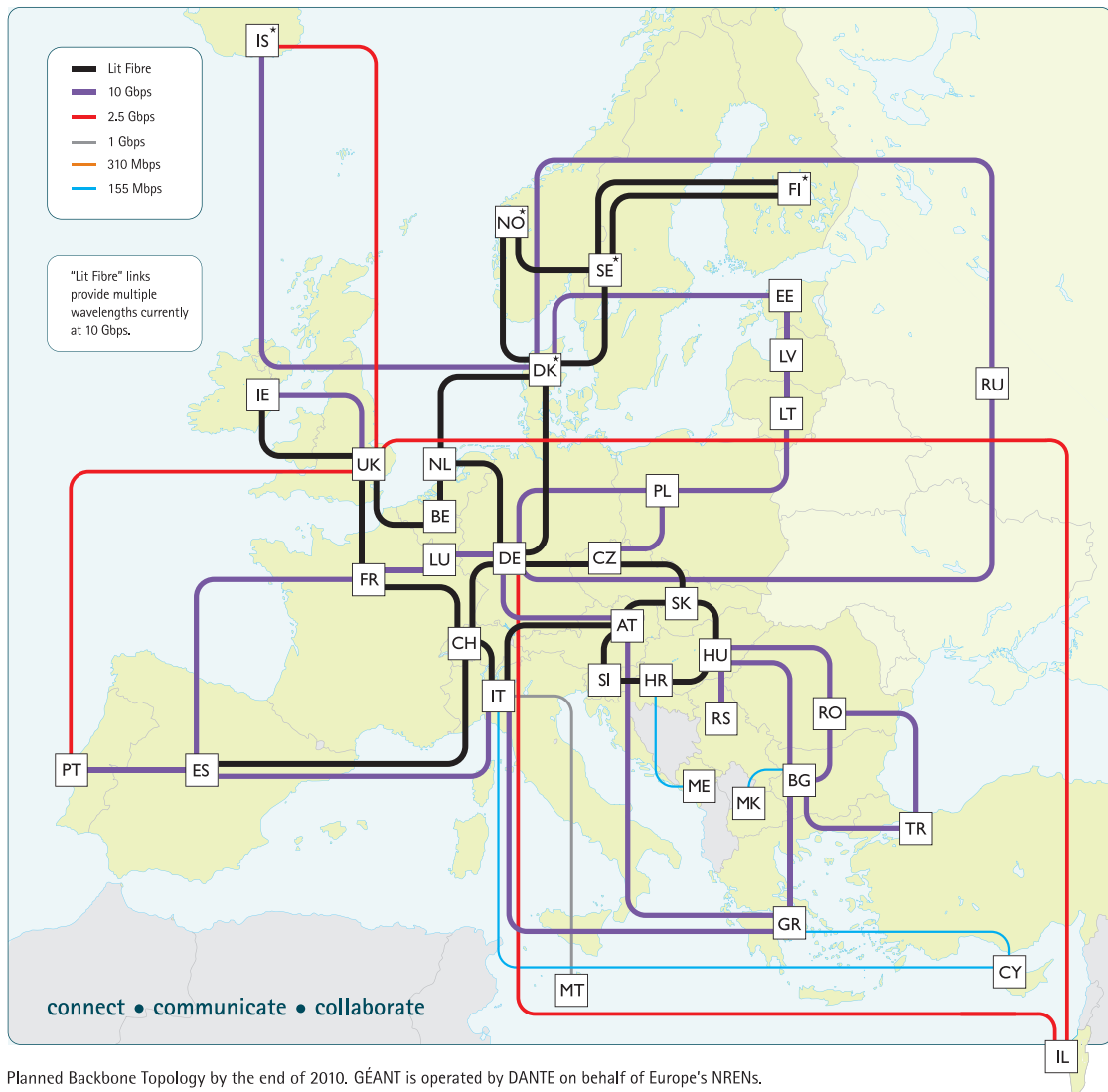
Figure 1: Capacity of NREN External Connections (EU/EFTA countries), 2010¹

¹ TERENA Compendium 2010, www.terena.eu

The GÉANT backbone accounts for only a small fraction of the European networks' overall costs. The current GN3 project, which covers the operation and development of the GÉANT backbone, has a budget of around €30 million per year, funded equally by the European Commission and the NRENs. This represents just a fraction of the total costs of the European academic networks, however, as the majority of the costs are borne at national and sub-national level, including in the 4000+ campuses connected to the European network. As a 'rule of thumb', the inter-national, national, and campus costs are in the ratio of 1:10:100: i.e. for each euro spent at international level, 10 euros are spent at national level, and 100 euros on campus infrastructure. This makes the total European market

for research and education networking worth several billions per year, a not insignificant part of which goes to European industry. A detailed understanding of the national (NREN) and campus/communities (user) levels is therefore essential to the development of a coherent strategy.

To put these figures into context, **the GÉANT backbone cost of some €30 million per year is around 0.013% of the total European research and higher education expenditures.** In comparison the yearly EU budget for research and innovation is about €8 billion and the combined EU + member state public investment in research and higher education is estimated at €225 billion.



1.2 The Current GÉANT Ecosystem

The national research and education networks serve a wide range of users, from high science to schools and libraries. Their core user community has been, and will remain, academic users involved in scientific research and in higher education more generally. In some countries, the networks also serve schools and other education institutions (Figure 2). But we must recognise that the community involved in research and education is expanding rapidly beyond traditional settings. Some networks, moreover, are developing beyond research and education into the

wider public sector. In the UK, for example, JANET (the UK NREN) is engaged as a partner under the Public Sector Network initiative, which aims to deliver a secure private internet for the public sector while also generating cost savings. It is also working, with health service and local government partners, in a project to aggregate public sector broadband in Wales. This public service aspect is a new and emerging market, and as yet relatively few NRENs are actively seeking to diversify beyond their traditional clientele. Under national legislation, some NRENs (e.g. DFN in Germany) are restricted to research and education users only.

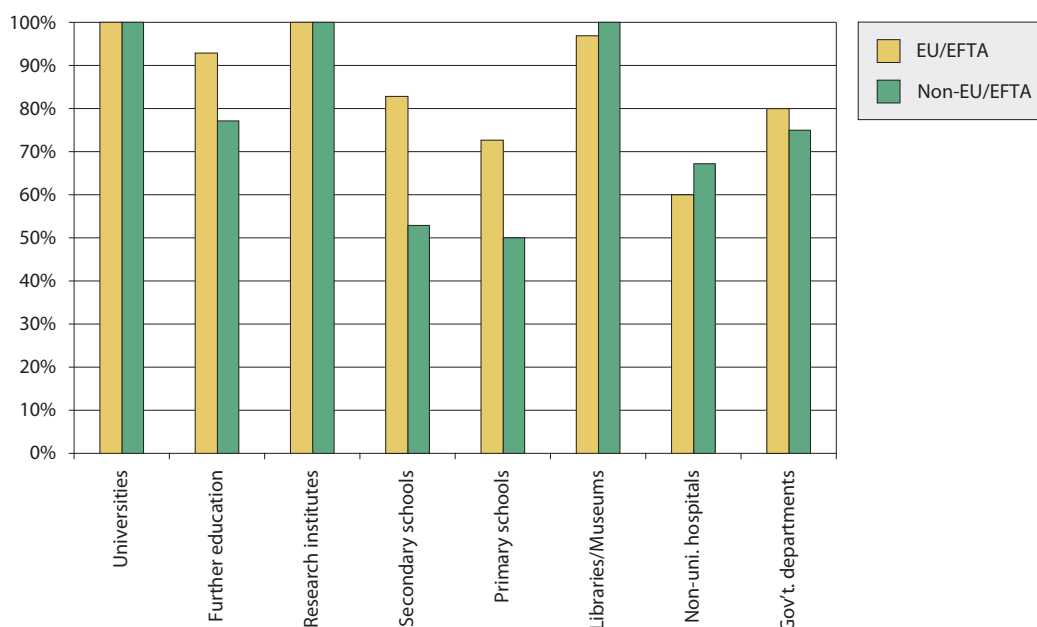


Figure 2: Connection Policies of European NRENs, 2010²

Connectivity is no longer a bottleneck. Today, most NRENs are based on dark-fibre networks³ and technology allows network capacity upgrades at limited additional costs, both within national networks and the GÉANT backbone (e.g. by using DWDM to light the fibres). Consequently, connectivity is no longer a bottleneck and most users effectively have access to

unlimited bandwidth (Figure 3). NRENs use diverse methods of connecting institutions: either directly to a NREN; via a MAN or RAN⁴ operated by the NREN; via a MAN or RAN not operated by the NREN; or via a peer with a connected site. In EU/EFTA countries, direct PoP connection is the most common, followed by connections via a MAN or RAN. In the non-EU/EFTA countries,

² TERENA Compendium 2010, www.terena.eu

³ 'Dark fibre' refers to optic fibre cable that is not connected to transmission equipment by the vendor or owner of the cable and therefore has to be connected (i.e. 'lit') by the NREN or the client institution.

⁴ A Metropolitan Area Network covers a geographic region such as a city. This term is often used interchangeably with Regional Area Network (RAN), which generally covers a wider geographic area.

PoP connections are more prevalent. As shown in the Figure, the bandwidths provided to the various user categories differ considerably and there is also great variation in the range of services provided. In some

countries Structural Funds have been used to leverage GÉANT investment. Portugal and Spain, for example, are in the process of interlinking their networks to create an Iberian Ring.

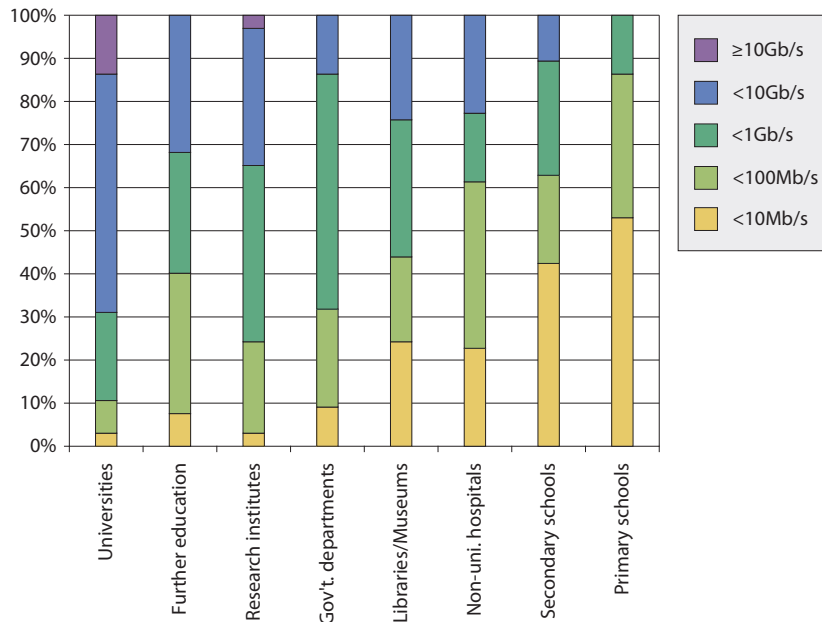


Figure 3: Typical Bandwidth by User Category, EU/EFTA Countries⁵

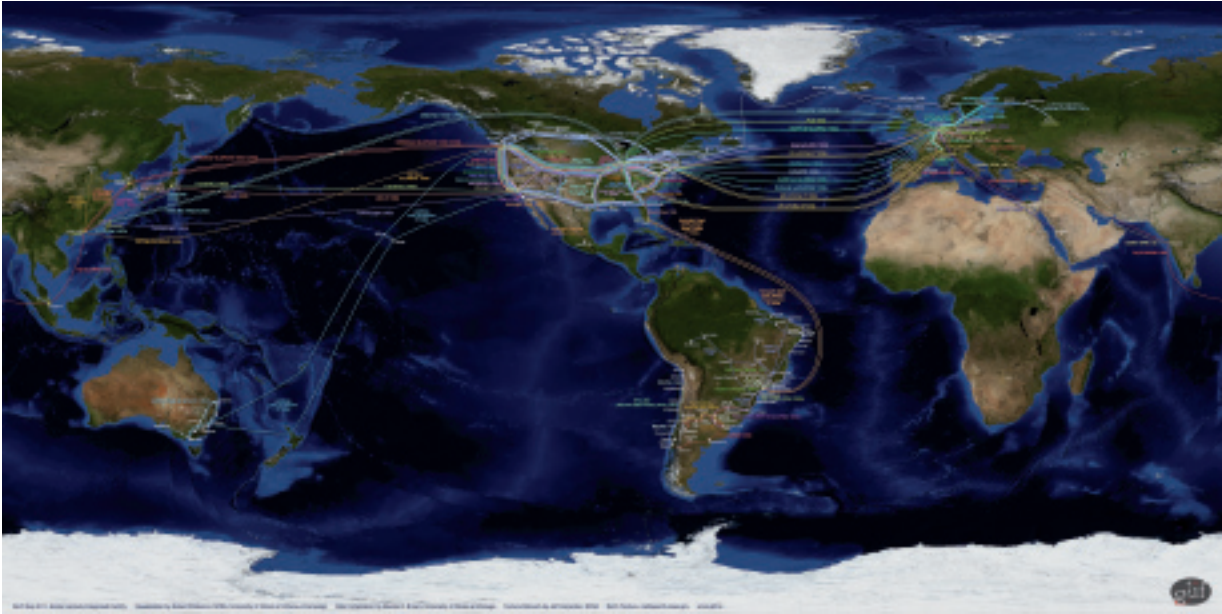
The European networks are founded on collaboration. NRENs collaborate closely in both operational and innovation activities, either bilaterally and/or under the TERENA umbrella. These collaborations are mainly on an informal basis, such as through participation in task forces and projects facilitated by TERENA on behalf of all NRENs. An exception is Nordunet, a more formalised structure bringing together Nordic NRENs which predates the establishment of TERENA.

Federation operates at many levels. The current structure is often described as a 'federated approach', meaning that the NRENs and DANTE work together as one community or unit. In practice, it is a good deal

more complicated than this: 'federation' is actually a multi-level concept that depends partly on organisational frameworks within the member states. At one level, the NRENs in Europe work together to organise certain services, e.g. through DANTE. At another level NRENs in a region may organise part of their connectivity and associated services in a regional context. Yet another level is formed by a particular user community bringing together, in a federated way, the global partners to create the integrated networking services it requires. Intercontinental connectivity is a fourth example of federation by certain partners; which partners come together may often be the result of calls for tender⁶.

⁵ TERENA Compendium 2010, www.terena.eu

⁶ For example, the Global Lambda Integrated Facility (GLIF) federates a cross-section of the research & education networking organisations worldwide in relation to light path services. See www.glif.is.



Map of the Global Lambda Integrated Facility (GLIF), 2011

NRENs face many challenges in how they operate: organisational, commercial, and regulatory. They have to meet the needs of their users while at the same time being part of a Europe-wide network. They have to engage with commercial partners who see them both as customers but also competitors. And as publicly-funded entities operating on the peripheries of a regulated market (telecoms), they are continually wary of competition law.

Especially important features of the current GÉANT ecosystem

Diversity of models: NRENs come in all shapes and sizes and no one form can be considered 'typical'. They range from organisations such as DFN (Germany), JANET (UK) and SURFNet (Netherlands) with 30+ employees, to those in smaller countries with only a handful of full-time staff. The differences are determined in part by the size of the local userbase and partly by national regulations and funding structures and also, in some cases, the political organisation of the country. Each NREN tends to have particular strengths and interests, but it is difficult to identify a single business model that is applicable across Europe. As noted above, they also organise in different configurations in delivering services to users.

Complex cost-sharing: GÉANT operates a cost-sharing model whereby the cost of the European network and services are apportioned across the partners according to an agreed formula. The model aims to ensure that costs are distributed in a way that is fair and equitable, related to underlying costs, encourages the use of new services, and diminishes the geographic divide. Factors that influence the subscription for individual NRENs include: access capacity (and type of access); costs of the circuits/dark fibre used; number of votes an NREN has (based on purchasing power parity and GDP). The model is flexible but quite complex.

Tensions between traditional and emerging roles: In terms of connectivity, NRENs face three types of demand from their users:

- Leading-edge activities in the research community. This depends heavily on GÉANT and historically has been the main focus for most NRENs;
- Common Internet services, such as a 'plain vanilla' IP service required by the standard user in research and education;
- New activities in public services delivery. Although important this is being considered separately, with little sign of NRENs wishing to mix traffic.

This diversification of activities can create tensions. Traditionally, NRENs have built capacity far in advance of need, which is a very un-commercial approach, but are increasingly being pushed towards behaving more like a commercial supplier where backhaul is limited⁷. However this approach of providing ample, cost-effective bandwidth together with user-defined networking characteristics can also be a source of innovation, since projects do not have to limit themselves to the parameters of commercial networks. In their response to change, NRENs face increasing conflicts whether to position themselves as 'intelligent customers' on behalf of the R&E community or to provide services themselves.

Emerging issues

Increasing competition for international connectivity: The fact that many of the NRENs' international links are provided outside of the GÉANT/GN3 framework makes for a very dynamic situation. High-end user communities exploit this dynamism to create their own global networks (e.g. for the data produced by the LHC accelerator at CERN). Effectively, there is no monopoly for international connectivity, nor should there be.

Opaque governance: Good governance is essential for the effective working of the research networks and is an area where the European system has generally performed well. Under the current structures – and despite several attempts at reform – users are not part of the governance, however. Increasingly, user communities need to have connections to multiple NRENs and the number and diversity of these situations

is expected to rise significantly in the coming years. In addition, efforts to move to an association model have been prolonged. This lack of transparency represents a challenge given the increasingly important role of users as stakeholders in the networks.

Heterogeneous regulatory environments: Research networks are a grey area in terms of regulation and are treated inconsistently by Member States. Although they are generally accepted as closed networks under telecoms regulation, moves to serve wider audiences in schools, hospitals and government departments mean they could be classified as public networks, and so draw complaints from commercial providers. As examples, SURFnet has been challenged by the Dutch Telecom Regulator concerning its practices⁸; and in Finland the NREN is registered as a provider of public communication services.

Lack of visibility: Research networks have an image problem. Tubes in the ground filled with optical fibres is not a visible or an attractive area for politicians, nor indeed for decision-makers in universities and research funding agencies. Consequently, the networks tend to get marginalised in discussions of research investment: a shiny new laboratory, an impressive telescope, or supercomputers can look much more appealing. Yet this situation totally underplays their significance to a modern knowledge-based economy. The position is particularly acute at campus level, where European universities are significantly underinvesting in networking capabilities to a point that threatens Europe's future position as a world-class player in scientific research. This funding gap must be addressed.

⁷ Backhaul refers to the intermediate links between the core network, or backbone, and the small sub-networks at the 'edge' of the entire hierarchical network. These links generally have more limited capacity than either the core or the sub-networks.

⁸ The regulator lost the case and at the time of writing was launching an appeal against this decision, which was still ongoing.

1.3 Markets and Users

The scientific and educational constituency served by NRENs is experiencing profound change.

Exponential traffic growth and changing profiles:
The volume of traffic carried over the networks is

increasing exponentially, with no signs of a plateau. Between 2006 and 2010, traffic carried by GÉANT increased three-fold (Figure 4), a pattern that is mirrored (and even amplified) at national and campus level.

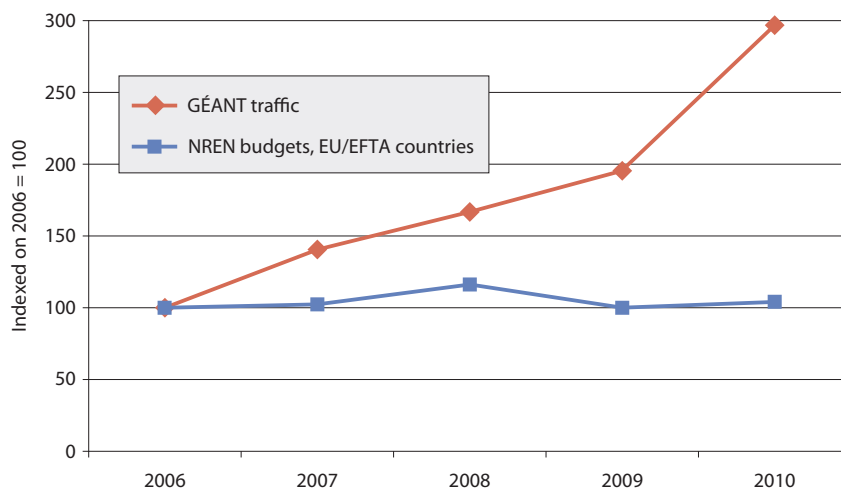


Figure 4: Budgetary and Traffic Growth, 2006-2010⁹

In the Munich Scientific Network (MWN), for example, between Dec 2005 and Dec 2010 traffic increased more than seven times to 800 TB per month (Figure 5).

Furthermore, there have been changes in daily traffic profiles as a result of new users, such as schools and students dormitories, who have different usage patterns to researchers. In MWN, the greatest demand on the network is from student dormitories during the early evening. Much more of the traffic is wireless, with the number of wireless access points growing rapidly. A multiplicity of devices means that the assumption of one user equates to one device no longer holds. Users are looking to access their data from wherever they are: in their lab, on the road, or via commercial networks. And with increasing emphasis on lifelong learning, the contents of university networks are being opened up to local communities. In short, the networks have

evolved from a purely professional to a more service use, and carry much more media-rich content.

Changing user expectations: At the same time, users' expectations are changing. In the beginning, RENS catered for advanced technology-savvy users. With an ever greater range of scientific assets and data available in digital form, the networks are attracting new communities from beyond traditional research and education and new uses beyond fast connectivity and high performance computing. In addition, new types of users are coming onto the scene, from areas such as healthcare and the public sector, bringing a different ethos and requirements (e.g. with respect to privacy) which need to be carefully assessed before opening up research and education networks. Such communities are not interested in networks per se but want them to support what they do.

⁹ TERENA Compendium 2010, www.terena.eu

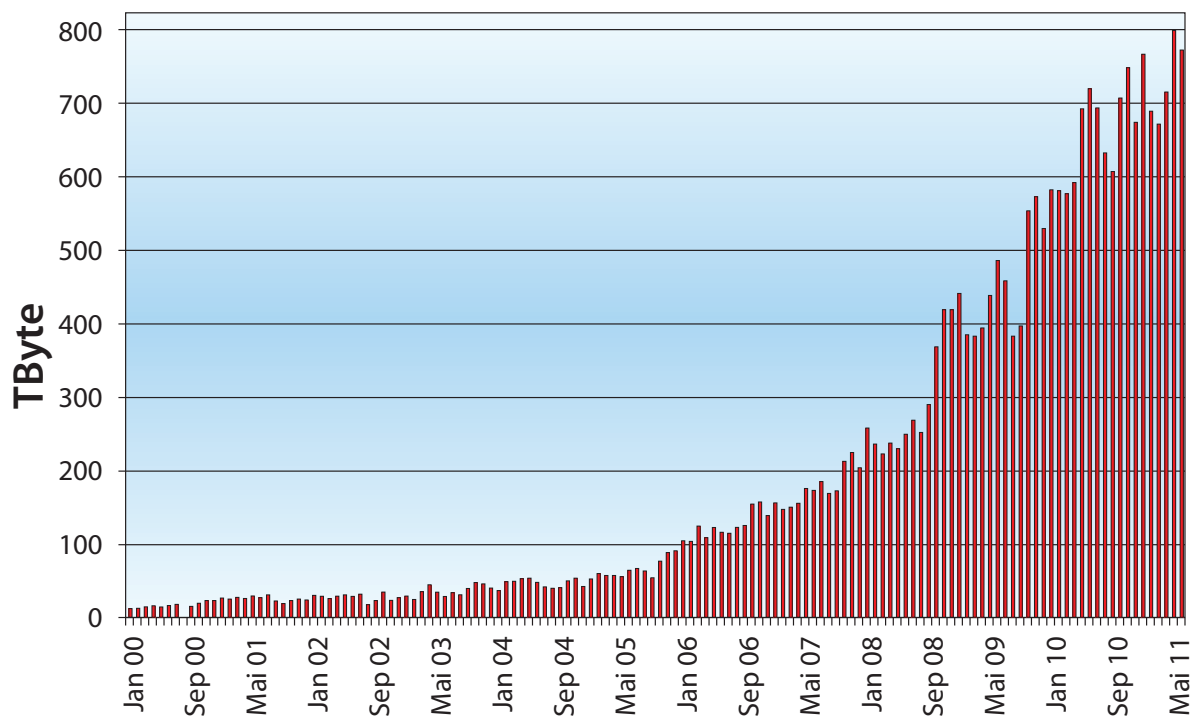


Figure 5: Traffic in the Munich Scientific Network MWN

Escalating demand from leading-edge users: This does not mean that the traditional users in Big Science projects have gone away. On the contrary: their requirements become ever more demanding. At CERN, the European Research Centre for Particle Physics, for example the commissioning of the Large Hadron Collider (LHC) has brought the need to capture, store and process terabytes (10^{12}) of data per day (see box 3). Networking requirements are prompting the establishment of 100 Gbps connections. European researchers

look to the networks to guarantee that they remain in a competitive position in relation to their collaborators around the world, in particular their US and Asian colleagues. Users must be guaranteed to connect to their research facilities from almost anywhere, in a way that is open, flexible, cost-effective and sustainable. As demands grow, end-users are looking for gigabit interfaces (so-called 'gigabit to the desktop'), even if the core networks themselves are not gigabit enabled.

Box 3: The Large Hadron Collider - Smashing the Limits of Data

The Large Hadron Collider (LHC) at CERN, the European Centre for Nuclear Research, near Geneva, is one of the most ambitious scientific projects of our age. Although physically located at the Swiss-French border, the LHC enables a community of around 20,000 high-energy physicists worldwide.

While famed for its 27km of particle accelerator, the project's data and connectivity requirements are equally impressive. During initial operations in 2009-10, the machine's sensors were generating data at a rate of 2Gbps, amounting to around 15PB (petabytes) of storage per year. Both these parameters are expected to double every 2-3 years as the facility becomes fully operational. In fact, LHC user requirements continue to evolve and as new capabilities become available the physics community is quick to adopt.

The initial ideas in the 1990s of using 622Mbps circuits rapidly changed to a grid computing model as international networking became substantially cheaper. During the implementation, the LHC community considered a number of options for meeting its connectivity requirements. Very high bandwidth has to be available around the clock and able to evolve to match the needs of the experiments and distribute data across the world. To satisfy the needs of the initial data distribution between the 11 principal centres a worldwide network was needed. This was formed through a collaboration of NRENs and GÉANT in Europe as well as other network providers and commercial companies in other countries and is called the LHCOPN.

In order to maintain competitiveness it was important that GÉANT circuits compete on a commercial basis with all other suppliers so that they can be replaced if they become too expensive. It is also common business strategy to ensure that there is never dependence for any service on a single supplier.

<http://lhc.web.cern.ch/>

Research in all disciplines becoming data-driven:

Such scientific projects are at the leading edge of the data deluge affecting all disciplines and sectors¹⁰. Global storage capacity continues to expand at an exponential rate. In life sciences, especially, the rate of growth far exceeds Moore's law; the European Bioinformatics Institute (EBI see box 4) is doubling storage every 12 months. JIVE can generate 1PB of data in an 18 hour session and next generation projects such

as the Square Kilometre Array (SKA) will be even more demanding¹¹. Even in the social sciences and humanities, an emerging and non-typical community, data requirements are escalating. Such large science projects tend to underestimate their IT requirements and always demand more than planned. In many communities data retention policies are still in their infancy.

¹⁰ For analysis see *Riding the Wave: How Europe can gain from the rising tide of scientific data*. Final report of the High Level Expert Group on Scientific Data, European Commission, October 2010

¹¹ The Square Kilometre Array (SKA) is a global collaboration to establish a radio telescope with a total collecting area of one square kilometre. Sites in South Africa and Australia are being considered for the facility and the project's operations centre will be located at Jodrell Bank near Manchester, UK.

Box 4: EBI - Innovating under the Data Deluge

Biomedicine and genomics is a fast-growing sector with major economic and societal impact. The sector is a major user of Europe's research and education networks.

Datasets here are growing at a phenomenal rate. Advances in gene sequencing technology and increases in available computing power mean a genome can now be sequenced in hours, rather than months, while new applications and clinical treatments are emerging rapidly. Thus, the sector has to ride the data deluge not just in undertaking research but also innovating for the commercial marketplace. Data are generated in a geographically distributed manner but require integration, while data analysis algorithms are becoming more compute intensive. Since some of the data refer to clinical cases, privacy issues also have to be taken into account. Bandwidth is a major bottleneck and demand to increase bandwidth are not expected to go away.

To address these challenges, the European Bioinformatics Institute (EMBL-EBI) is looking to minimise the movement of data, bringing the compute power as close to the data as possible through 'virtual machines'. Algorithms are being parallelised, effectively creating a Grid solution, while cloud solutions are also being explored where commoditised data and computing can be utilised. User training is an important issue and is being integrated with service provision, enabling a large and diversifying audience to learn about bio-molecular data resources and tools.

www.ebi.ac.uk

Open Access initiatives in many scientific communities: The Berlin declaration on Open Access to Scientific Knowledge of 22 October 2003 motivated the creation of multiple initiatives of many scientific and academic communities and is becoming a powerful means to give access to knowledge, information, and data. This is essential in higher education and research, and more generally for sustained progress in society. This immediate, online, free availability of research outputs without the restrictions on use commonly imposed by publisher copyright agreements can be a fundamental means to increase innovation. Open access will have an impact on NRENs since it will increase the volume of data in scientific repositories and the pressure on connectivity of these repositories at a global scale.

New trends

These trends are forcing NRENs to move away from simply delivering connectivity to focus on two additional aspects: services and innovation.

Research and Education networks are becoming increasingly a service environment. Users have welcomed the introduction of services such as Eduroam and AAI¹² and take-up has been enthusiastic. These are becoming essential features of the network and demand from academic users and others is certain to increase. Current services (not all of which are provided by the GÉANT community) are often not user-friendly, however. Moreover evidence presented to us suggests there are major gaps and shortcomings in service provision. For example, there are no ready-made solutions, nor even guidelines, for contracts to establish an identity federation and users have been left to work it out for themselves. Virtual organisations and security are other areas where timely advice has been lacking. Users also complain of a confusing landscape: they are looking for a 'one-stop-shop' with one clear point of responsibility (similar problems, in fact, are occasionally to be found at a national level). International organisations and global virtual research communities, especially, have experienced

¹² Authentication and authorisation Infrastructures (AAI) are identity management systems used to accredit users so that they may gain access to a variety of services through a single authentication mechanism that manages a scientific user identity in a simple but secure way.

difficulties since they fall outside individual NRENs' national remit.

Innovation is an underrepresented feature of NRENs. In addition to their infrastructural responsibilities, in some countries innovation is an element of NREN funding. To some extent this is the case at the European level as well, where activities are led by GN3, a consortium of NRENs coordinated by DANTE. GN3 has identified several key priorities such as: seamless multi-domain networking; flexible bandwidth-on-demand (BoD) and lambda-on-demand capabilities; executing testing at 100 Gbps including over long distances; a feasibility study into the expansion of Eduroam; and facilitating a common European AAI mechanism. These will help to establish a European virtual network capability to support generic testbeds of network technologies¹³. The planned review of network infrastructure requirements for ERA, in particular ESFRI projects, might lead to other innovative solutions.

Campuses are getting left behind. Many universities and colleges have difficulties to afford the new interfaces to the high-capacity networks being developed at European and national levels. Indeed, in some countries national policies towards innovation specify that NRENs stop at the campus gate. This lack of investment in state-of-the-art facilities and human

resources at campus level is at the heart of the funding gap referred to above. It creates problems in providing end-users with high quality networking services. NRENs can play a significant role in helping to deploy best practices inside each territory where, traditionally, they are a source of technical expertise.

1.4 Time for Renewal

Europe has demonstrated considerable successes, but we cannot be complacent. The European networks face unprecedented challenges as a result of changes within both their own ranks and the communities they serve. As we discuss in the following section, these factors are exacerbated by wider trends influencing the creative knowledge economy. Aggressive investment is taking place elsewhere. Science is reorganising itself as a response to powerful new data, communication and computing possibilities. The networking infrastructure must reposition itself too.

The situation is critical and Europe risks losing out. The world is changing fast – both in terms of demand pull and technology push – and we need to adapt. Past achievements are no guarantee of future success and Europe faces stiff competition. It is time to reassess the requirements and renew the European networks as a key 21st century infrastructure.

¹³ This relates in particular to initiatives such as FIRE (Future Internet Research & Experimentation) and the Future Internet PPP.

2 Welcome to the **Borderless World**

The environment served by GÉANT – the sphere of research, innovation and learning – is experiencing profound change. In this section we outline the challenges and opportunities arising from this wider context, as a basis for the vision and recommendations which follow.

Our themes are fourfold: changes in the global context and the need to seek innovative solutions to societal challenges; changes in the nature of the scientific process and the movement of research and learning beyond traditional settings; changes in the nature and context of innovation across the economy and society; and the continuing evolution of technology which promises exciting new approaches to data and information.

In the resulting Creative Knowledge Society, success – for individuals, enterprises and countries – depends more than ever on a fruitful competition of ideas. In this digital and highly interconnected world, knowledge, innovation and learning flow readily, unconstrained by the distances and boundaries of former times. It is a world without borders, where talents from around the world compete openly and understanding and creativity are the sources of competitive advantage.

2.1 COMPETING IN THE GLOBAL KNOWLEDGE-BASED ECONOMY

Globalisation continues a pace, with the so-called BRIC countries accounting for a rapidly rising share of global GDP. With their young – and fast-growing – populations, excellent education systems and fast-improving standards of living, they are eager and agile; Europe will have to leverage on its specific strengths and values - like the focus on privacy, intellectual properties, local diversity, social values, high standards of living - if it is to compete with them. This is

especially true of science, where the share of scientific output from the BRIC economies has been growing rapidly. China now has the third largest output of scientific papers after the EU and the US. The EU share of global scientific output by comparison is declining. However, since the almost instantaneous availability of information makes it irrelevant where that specific information is generated, the crucial aspect becomes how to make use of the information. The “think global, act local” applies.

Knowledge and openness to new ideas will be essential in tackling the challenges ahead. Climate change, energy and resource scarcity are major policy drivers for the 21st century, affecting everything from the macro to micro levels. Meanwhile, Europe is experiencing major demographic change, with wide-ranging policy implications from health and social care, to lifelong learning and access to public services. We see automation everywhere including in service industries, and the continuing march of digital communications in all its forms. All of these areas demand innovation and creativity and a willingness to seek new solutions.

In ICT, labour costs will be a progressively less important factor in competitiveness. Beyond 2020 we can expect that the same decrease in transaction cost that has characterised the previous two decades, and is still affecting the present one in the ICT area, will be seen in the production chain. The trend of outsourcing manufacturing to Asia may well be reversed as a consequence of lower salary differential and the marginal impact of salary on the final product cost. At the same time products will embed an enormous flexibility, allowing them to be mass produced and customised at the point of sale. The ICT infrastructure will be the real differential factor.

Thus, Europe has to position for change. As the post-industrial society recedes and the new knowledge-based economy emerges, Europe has just one choice: reform or decline; embrace change rather than retreating to the safe, old ways of the past¹⁴. Europe must embrace growth through knowledge, empowering the individual and stimulating creativity and innovation across the economy and society. Europe has a significant market, big enough to provide the required economy of scale. It can and will export those products and services that have been demonstrated to increase the well being of people and society. The real risk is to see a Europe lagging behind, importing “well-being” from other parts of the world along with a way of life, and ethical values, that may not fit its specificity. Europe needs to lead for the sake of its own citizenship and society and take part in the global trade of products and ideas.

The European Research Area (ERA) is a key enabler of a knowledge-based economy and society. In the 2020 Vision for the ERA, the Member States and the Commission have agreed to develop the ERA in ways that contribute to the sustainable development and competitiveness of Europe. In particular, the ERA vision enshrines the so-called “fifth freedom” – the free circulation of knowledge – as a building block that supports the free movement of knowledge. In the ERA all players should benefit from attractive conditions for carrying out research and investing in R&D intensive sectors in Europe; as well as healthy Europe-wide scientific competition, together with the appropriate level of cooperation and coordination.

In placing the free movement of knowledge alongside the free movement of people, goods, capital

and services, the ERA implies that there must also be common infrastructures. Just as Europe’s people and goods have common physical infrastructures, and capital and services have common European regulatory frameworks, so **knowledge requires common European infrastructures to flow without friction.** Since knowledge is an intangible, many of these infrastructures will be digital. Electronic infrastructures – or e-Infrastructures – are an important tool in bringing research communities together, enabling global virtual research communities, and facilitating research and research innovation.

In the next decade these digital infrastructures will expand to include the environment (sensors, actuators, etc), ambient (public and private dwellings) and will eventually reach products, not to mention the digital social life of citizens. The ease with which the features of a product may be changed will create a potential open lab where the boundaries between lab and in-field experimentation will become ever fuzzier. This should not happen without respecting our shared values and rules implementing them. Hence this is a new, extended role, for the European Digital Infrastructure.

Europe’s global peers are investing heavily in both research networks and societal broadband infrastructure. For example in the United States, the Broadband Technology Opportunities Program (BTOP), part of the American Recovery and Reinvestment Act, has earmarked over \$5 billion for a new national networking infrastructure, with a focus on services to R&E networks and community anchor institutions. Over \$1.5 billion is being invested in R&E network related capital upgrades and a further \$4 billion for

¹⁴ For further insights here see: Project Europe 2030: Challenges and Opportunities. A report to the European Council by the Reflection Group on the Future of the EU 2030, www.reflectiongroup.eu

advanced broadband. The community strand (known as US-UCAN¹⁵) will leverage the Internet2¹⁶ Network infrastructure to provide services to community anchor institutions, including schools, libraries, community colleges, health centers, hospitals and public safety organizations. It is closely related to (and dependent on) similar efforts being undertaken at regional, state, and local level (e.g. the deployment of 'middle-mile' infrastructures). Once completed, BTOP will be almost 20 times bigger than Internet2 and the National Lambda Rail (NLR)¹⁷ are today and will have almost twice as many owned-miles of fibre as NLR.

In Europe, the research networks can continue to make an important and valuable contribution to policies for both the European Research Area and the Digital Agenda. Under the Digital Agenda, Europe has set targets to bring broadband to all Europeans by 2013; and at least 30 Mbps for all by 2020, with 50% or more of European households having access above 100 Mbps. With their public service ethos and European reach, the networks can help close digital divides, especially within the worlds of research and education, and help drive public sector change in areas such as health and public administration. This connection between the research labs/infrastructure and the everyday life of citizens is very important and would multiply the impact of research, taking on board citizens.

2.2 NEW MODELS IN RESEARCH, INNOVATION AND LEARNING

Research and the New Science

Over the last 20 years the nature of the scientific process has changed beyond all recognition. 'Big Science' projects, which were once confined to a few communities such as high-energy physics, are now found in virtually every scientific discipline, including the social sciences. CLARIN¹⁸, for example, is a European research infrastructure for language resources

and tools that is accessible to (mainly non-technical) researchers in the humanities and social sciences. These big science projects rely on multi-lateral, and often global, collaborations between researchers all over the world. Such users need to be able to combine seamlessly, connecting together to share data, discuss results and formulate conclusions; often it is multidisciplinary collaborations that are the most productive.

In this decade, and more so beyond 2020, we will witness a progressive cross-fertilization across many research disciplines. What have been ever growing, but separate silos of knowledge, will tend to become more permeable and eventually research activity is likely to flow across all of them. This multiplies the challenges to the supporting infrastructure, specifically in being able to make data (semantically) accessible whilst maintaining the required guarantees of protection and ownership. Very possibly an extended ontology covering all research areas will become necessary to support this cross-feeding of research. This has an impact on data centres that in a GÉANT vision should become part of the infrastructure itself.

E-infrastructure is the nervous system of this New Science. With the research process becoming increasingly data-driven, scientists rely on high-speed networks such as GÉANT to access remote instruments, to mine data in digital repositories, to process and visualise their data on high-end computing resources, and to undertake experiments *in-silico*. The research community is both user and supplier in an integrated e-infrastructure ecosystem and European researchers need the very best to compete on the global stage.

Big science organisations routinely present the most challenging requirements for the research networks; their high-end users such as CERN, the EBI and ITER demand both stable production services and innovative service enhancements. The bandwidth demanded by large scientific projects is much greater

¹⁵ US Unified Community Anchor Network

¹⁶ Internet2 is a not-for-profit advanced networking consortium comprising 221 U.S. universities, in cooperation with 45 leading corporations, 66 government agencies, laboratories and other institutions of higher learning, 35 regional and state research and education networks and more than 100 national research and education networking organizations representing over 50 countries.

¹⁷ National Lambda Rail is a 12,000-mile (19,000 km), high-speed national infrastructure owned and operated by the US research and education community that runs over fibre-optic lines, and is the first transcontinental 10-Gigabit Ethernet network.

¹⁸ www.clarin.eu

than that within the mass-market, with applications such as physics research, holographic rendering and hi-definition mash-ups having requirements of many hundreds of Mbps or more. Demand from these advanced users will continue to stay ahead of what is available commercially at affordable prices and, properly addressed, this creates an engine for innovation for society as a whole.

In science, as elsewhere, social networks are also having a profound impact. While Facebook and Twitter are not yet major platforms for scientific discourse, the research community is developing its own forums that bring scientists together online to share their data and content. There are both opportunities and risks in such networks: on the one hand they create possibilities for professional scientists to collaborate, including with amateur 'citizen scientists' who often have much to contribute. On the other hand, the digital life of people connected to the internet and particularly to social networks is object of scientific studies which raises all kinds of concerns. At the same time, there are issues around data ownership and security, since researchers are not willing to give away their data without appropriate safeguards.

For scientists to be able to navigate this increasingly complex web of people, data and resources they must have a trustworthy networking environment. The New Science needs a dependable and verifiable chain of trust relationships linking researcher to institution to research community, facilitating seamless and trusted access to data, content and services wherever they are located. NRENs have made tentative steps in creating these so-called 'federated services', notably through Eudroam and AAI. So far, however, user experiences have not been positive due to too few services being available and patchy service delivery. The barriers are principally organisational and legal rather than technical, but finding effective solutions both at European and global levels, will be essential for the future of scientific collaboration.

Education

In higher education, digital learning, lifelong learning and multidisciplinary are defining trends. As a result, university campuses are becoming increasingly virtual, creating a need for new collaborative tools and services. Academics and students alike expect end-to-end connectivity and limitless bandwidth, including in the wireless domain. As the poor relations of the networking world, campus networks often struggle to cope and are becoming a bottleneck in the overall infrastructure, making investment policies a key issue.

Higher education institutions will play an increasing role in life-long learning, producing media-rich courseware and other kinds of educational content that will shape new learning environments. Many of these will be available on open access terms in the multi-lingual and multi-cultural environment that characterizes Europe, but is also relevant to the many places in the world where European languages are widely used.

Similar changes are evident in schools. New, more learner-centric approaches to teaching are being employed; digital tools and resources are being used across the curriculum, while gaming and infotainment are widely seen as an important part of future learning. For instance, one recent study (based on US data) estimates that by 2020 80% of all college education will happen online, and 50% of all college campuses will have either closed or be transitioning into a different kind of institution¹⁹. While talk of "the end of going to college" may be premature, the direction of travel is clear and the education system of 2030 will certainly be very different to that of today.

These trends further extend the scope of GÉANT.

¹⁹ *Rethinking education*, Thomas Frey, DaVinci Institute, 2011. www.davinciinstitute.com

2.3 DIGITAL NETWORKS DRIVING INNOVATION IN INDUSTRY, BUSINESS AND PUBLIC SERVICES

Increasingly, we see that digital technologies are changing the nature and context of innovation across the economy. This is especially true of digital networks, which are one of the main facilitators of open and user-driven innovation. Empowered by near-limitless bandwidth, firms can seek out innovation opportunities wherever they are to be found and collaborate closely with suppliers and customers, including end-users. Innovation is migrating out of the laboratory and development centre and into real-world settings. Furthermore, today's knowledge workers are increasingly mobile, meaning that Europe has to compete for the best talents worldwide, in science, business, industry and public administration.

However, today many enterprises still see ICT as an "automation" tool and not as a way to deliver more services or extend their products. This is usually left to start-ups, which tend to be more active in the USA than in Europe. We can expect that the profound changes in the marketplace and the growing competitive pressure will have changed this scenario in Europe by 2020. Increasingly, the competitiveness of SMEs is likely to depend on access to research results and to the possibility of contributing to the transformation of research results into innovation in their specific field.

The research networks tend to be at the most innovative end of the spectrum, dealing with the most demanding applications and uses of advanced networking technologies. They provide European ICT suppliers with a testbed for the most advanced hardware, software and services.

However, the research networks are not well linked to innovation activities elsewhere. Recognition of open innovation and the value of networks have led Europe to invest in the Future Internet²⁰ as a societal enabler. The Future Internet is the focus for a great many consortia and projects, both at European

and national level, aiming to develop technology and applications for the general-purpose networks of tomorrow. Links between these two communities – research networking and Future Internet – are relatively weak, however. Yet the two are complementary: research networks can provide robust and reliable environments for prototyping and validation of next-generation networks and applications, while the Future Internet world (which has more industry players) can help pull through successful innovations within research networking.

Europe's commercial network operators are facing major challenges:

- **Making mobile services profitable and sustainable:** The relentless growth in data traffic and the rise of the mobile internet put large service providers in an uncomfortable position. Mobile data traffic is predicted to grow around 30 times over the next five years, with internet-over-mobile accounting for over 70% of mobile data by 2014²¹. Already today, typically around 85% of the traffic carried by a European commercial service provider is data and only 15% is voice services, yet the latter accounts for 85% of revenue. Thus, in boardrooms across Europe executives are trying to square the economic circle: how to continue to expand the network while at the same time generating revenue from the relentless demand for mobile data and services. Some (though not in Europe) have sought solutions in creating closed gardens in place of the open space web.
- **Major changes in network traffic patterns:** Growth of popular applications, such as user streaming and transfers between data centres, are generating more local traffic, resulting in less being pushed into the top tier. For some services latency is becoming a competitive factor, requiring the latest optical technologies. Meanwhile, optical equipment manufacturers (many from outside Europe) are influential and exercise a lot of market power.

²⁰ www.future-internet.eu

²¹ Modelling by Bell Laboratories

- **Minimising transport costs:** With the investments made over recent years, bandwidth is no longer a scarce resource. Nevertheless, for commercial providers the cost-per-bit transported is still a key driver in investment decisions. The internet is getting flatter and opening up to new distribution models (e.g. managed fibre and dark fibre). One such model could be for the NRENs to offer integrated wireless services to help ease congestion in mobile networks: the university would take the data and use the mobile network for free, perhaps with contracts negotiated centrally.

Commercial network operators' relations with GÉANT are generally amicable. Networks are good customers of telcos e.g. €98m is subcontracted to telcos in GÉANT. Industry generally values the NRENs' unique position as a gateway to a truly global cutting-edge community and network. NRENs are seen as good customers because they 'push the envelope' technically and commercial providers appreciate working with an aggregating body able to provide specialist expertise. In some cases, however, commercial providers have viewed NRENs as competitors, especially where they have sought to diversify into public sector network provision, moves that are seen as threatening the operators' commercial models. Operators and vendors are also concerned about EU tender rules, which constrain the length of partnerships and contracts, creating obstacles in the way of long-term relationships.

Commercial operators are already finding an increasing market in research and education networks. In the next ten years the extent of commercial provision will increase even further, while costs will decrease. Even so, it is clear, from both technological and cost points of view, that the commercial advances on their own will not be sufficient to cater for the data deluge. The key question then arises: which aspects should be met by commercial providers and which by NRENs, and what should be the optimum balance between them?

2.4 TECHNOLOGY BRINGING NEW PARADIGMS FOR DATA AND INFORMATION

The evolution of networking technologies is stable in the core network but significant novelties can be expected by the end of this decade in the access area. First, the growth of mostly wireless local networks will create several alternative access infrastructures. Part of these will be made up by terminals, each one becoming a network node. This will multiply capacity and will give rise to alternative communications paradigm (e.g. delegation of data transport at the edges leveraging storage in terminals). These edge networks are likely to be autonomous (autonomic systems) and viral (dynamic mesh networks). This will substantially change the business scenario, particularly for operators. Second, the massive use of extended MIMO at the terminal level will effectively get rid of the interference problem, thus multiplying the capacity of the spectrum. Third, we can expect that the widespread presence of Internet of Things (sensors, tags) will create the need for parasitic connectivity, thus de facto creating another form of connectivity based on mobile gateways. Cars, for example, might be used for this.

Technology is evolving fast and Moore's law is holding. Unlimited bandwidth is opening the way to new networking applications, while developments such as fibre and advanced mobile will bring the always-on everywhere vision closer to reality. It is expected that many areas will be covered wirelessly through ground-based stations and, a minority in Europe but perhaps not a minority in Africa, via satellite links.

Key technological drivers

In technological terms, therefore, we see the main disruptions to the networking environment coming from the coalescence of existing technologies and the aforementioned breakthroughs. Key drivers are the following:

Unlimited bandwidth opening the way to new applications: Developments in networking technologies have now reached a point where bandwidth is no longer a barrier. This is opening the way to new and demanding applications of networking that are

significant both in their contributions to science and in driving innovation in the economy. In the mass market, as well as in the visualization of scientific data and cooperation among scientists, the increased demand for bandwidth is to great extent related to better displays with 4k and later 8k resolution.

Increasing significance of mobile: In recent years we have become used to a world of ubiquitous connectivity. This trend will continue as both fibre and 4G wireless networks bring the always-on everywhere vision closer to reality. In terms of the research community, this means greater account will need to be taken of (third-party) mobile provision within the research networks, both within campuses and beyond. . Mobile, however, will remain attached to personal communications. On the other hand, the much greater capacity offered by fibre will support ambient-to-ambient communications, where several head-up display (HUD) screens – absorbing as much as 200 Mbps (8k) each – will create a sense of ambient presence.

A world of unlimited storage: Storage costs continue to fall, supporting the data deluge. This storage is found not only in physical data centres but also in the multitude of smart networked devices we see around us (PCs, smartphones, tablets, etc.); these resources too could be available to be shared, creating a world of unlimited storage.

A world of make believe: The progress in display technology leads to resolution exceeding that of the human eye (4k and beyond), thus allowing the creation of presence sensation. Graphene screens, for example, are as thin as varnish and can overlay basically any object thus tremendously increasing the interactivity with the environment and multiplying the demand for bandwidth. Touch will become an essential component in the interactivity and this poses stringent requirements on the network architecture: less than 1 ms delay for perfect touch sensitivity. The advances in visualization technologies and in interactions are likely to lead to a new type of immersive labs, which may impose very high bandwidth and massive data storage requirements on the research networks.

Ubiquity of data: The wide availability of territorial (sensor) data will create many open labs where data can be harvested for scientific purposes and experimentation can take place. This is important for the research networks which may be directed to provide not just the backbone service but also local (wireless) area service and connect them to the backbone.

Virtualisation: Largely as a result of the above trends, major resources such as networking, high-performance computing, data repositories, and data visualisation are increasingly being virtualised. As a result complex and/or scarce resources are available to the community and securely shared from anywhere.

New approaches for security and trust: As the research networks are exposed to new users and take on different functions, we need to look again at issues such as security, privacy and trust. In terms of information assurance, the current approach is typically 'secure the network' rather than 'secure the application' and 'secure the data'. This in turn has implications for virtualisation and separation of traffic.

Greening of ICT: ICT accounts for a growing share of global power consumption and improving the energy efficiency and reducing the environmental impact of ICT will be a major factor going forward at all levels, from large-scale data centres to mobile devices. Options include relocation of processing and storage to centralized facilities and furthermore, to relocate them to locations with more convenient climate or electricity availability so as to relieve the cooling requirements and/or take advantage of renewable energy. Either way there could be major implications for the network requirements and its configuration.

Cloud computing: Many of these trends come together in so-called 'cloud computing'. Ubiquitous connectivity, unlimited bandwidth, the proliferation of smart devices and the user-generated 'app' culture all point towards the cloud model replacing more conventional paradigms in the medium to long term. Consumers and enterprises alike are embracing the cloud model which offers not just raw connectivity but also applications, content and services.

The extent to which such models will take hold in science and other markets relevant to NRENs is open to debate. To date the research community has generally not moved aggressively towards cloud services because of concerns over quality of service and data ownership. And in the public sector in general, the

use of private cloud services is controversial due to data protection and security issues. Nevertheless, with public agencies seeking to improve services at a time of shrinking budgets (especially for ICT), this is an area where we can expect new solutions to emerge.

Scenario: Network Access Requirements in the European Research & Education Community in 2020

By 2020, access requirements are expected to be at least one order of magnitude greater than today for all user groups:

- **Individual researchers:** 10 Gbps in the lab, 1 Gbps in the office, 50 Mbps anywhere else, including mobile.
- **Universities and research centers:** Multi 10-100 Gbps access + virtualization at all layers through various technologies.
- **Specialist users:** (Scientific/educational data centers & cloud providers, HPC campuses): Multi 100+ Gbps access, multi-layer virtualization, low latency requirements
- **Schools:** Multi 1 Gbps multimedia services (ultra HDTV, telepresence, access to the educational cloud)
- **Public buildings:** Assume fibre to all public buildings.

3 A Vision for 2020:

The European Communications Commons for Knowledge, Innovation and Learning

Research and innovation are central to Europe's future prosperity and well-being. New solutions resulting from research, development and innovation will be essential for Europe in improving its global competitiveness, tackling the societal challenges such as ageing and better public services, and building a green and sustainable future. To achieve this Europe needs world-class science and education, and a world-class infrastructure for supporting education, research and innovation. An innovation engine for 2020 is urgently needed.

Research and education networks provide an essential support for this engine. Europe's ambitions for research and innovation can only be met by ensuring European researchers have access to the best possible e-infrastructure services. Ultra-high speed, high capacity network services are an indispensable element of these e-infrastructure services, and in fact the foundation on which the whole edifice rests.

With its European reach, GÉANT 2020 will be a key driver of European research, innovation and learning across societal and economic sectors, and a training ground for the next generation of scientists and innovators.

Our vision for "GÉANT 2020" is as the European communications commons, where talent anywhere is able to collaborate with their 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** Support knowledge communities by providing world-class connectivity and services.
- 2** Support the growth of these communities, in both breadth and depth within Europe, and opening up to talent beyond the borders of Europe;
- 3** Push the state-of-the-art of the communication commons by constant innovation and by translating this innovation into a competitive European ICT sector;
- 4** Reorganize to cope with the constantly changing environment.

These are addressed in detail in the next subsections. 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 must remain true to its mission as an enabling e-infrastructure with European and global reach. It should be a conduit for Europe's researchers to collaborate and share knowledge; and it should be a central hub of a global communications commons, strengthening the position of European science in the world. It should be driving the evolution of global scientific and learning communities. As a communication commons, all users and countries should be able to access on equal terms irrespective of their status or location. While there could and should be closer involvement with commercial providers, the networks should remain non-profit entities. In principle services and resources should be open and accessible to all.
- **GÉANT 2020 as a collaboration platform:** The world is becoming smaller and across all fields of science and business the future relies on collaboration. To excel, Europe's talents – in research, industry, universities and elsewhere – must be able to collaborate with their peers anywhere in the world, unbounded by network, resource or service constraints. This requires a world-leading infrastructure and services oriented around users and their needs.
- **GÉANT 2020 as an environment for knowledge creation, innovation and learning:** While traditional science communities will continue to be important, they are no longer the only constituency that can benefit from a European communications commons. Knowledge creation, innovation and learning are expanding beyond

conventional settings and institutions and by 2020 will permeate the economy and society; the networks must actively facilitate this.

- **GÉANT 2020 as a transformative digital ecosystem:** To meet the above ambitions, GÉANT must throw off the limitations of the pre-digital age and establish itself as a truly open and global digital ecosystem. The institutional realities and borders set up for the real, local, material world, should not constrain the networking of the virtual world. Systems, procedures and regulations designed for the previous era are not necessarily those best suited for 2020. Organisational setups, business models, governance structures, funding regimes, regulation: all must be adapted and updated and where necessary new ones put in place.

GÉANT 2020 is rooted in values of equality, solidarity and freedom which are held in high regard by Europeans. It is a critical European networking infrastructure serving a well-defined and well-established core community, science, in the first place publicly funded research, and higher education funded largely by governments and citizens. The networks themselves are largely supported through public funding. They are seeking solutions that satisfy requirements high on public agendas such as trust, security and privacy. Through collaborative structures, they aggregate demand more efficiently than could be achieved by national players going to the market individually. And from a technology perspective, they feature multi-vendor, multi-domain open environments that are not normally available from the commercial providers.

The case for European public funding of vital international parts of GÉANT 2020 thus rests on three pillars. The first is a direct translation of the rationale for public funding of research, which is to ensure that society

captures the benefits of research when there is risk of private underinvestment because social benefits are larger than private ones. The second pillar is formed by their essential European nature. The third is their role in realising key public values such as trust, security and privacy.

Providing European public funding underlines the key element of our vision, namely that GÉANT 2020 is a commons, an ecosystem, a truly open infrastructure.

3.1 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.

- Offer value-added services to enable researchers to access the research networks from any location.
- Offer an inexpensive and diverse range of basic services made cheaper by pooling buying power of the core community and utilizing the specialized know-how of RENs.
- Offer high-speed bleeding edge services, using end-to-end optical paths on demand, for serving unique large research instruments – such as those defined by the European Strategy Forum for Research Infrastructures (ESFRI) - and support data centre interconnection, ahead of those available from commercial providers.
- Offer services (e.g. federated identity services) to create a chain of trust that spans from the individual researcher to the institution, to the global community.

To achieve this goal, appropriate investments must be made in the networks at all levels, from campus/local level through to the European-wide and global backbones, ensuring that pooling of investment resources takes place at all relevant levels in order to ensure cost-effectiveness and tackle the risk that the weakest link determines the ultimate functionality.

The networks must evolve into service-enabled infrastructures:

- Put users and their requirements centre stage. Networks should focus on users and user communities with differentiated needs which may call for a cultural change.
- Provide access by end-users (scientists, students, teachers, virtual communities, etc.) to integrated resources as a service e.g. HPC, data, remote instruments, commodity computing services and generic e-science tools such as visualisation.
- Offer seamless, secure and scalable connectivity integrated with requirements imposed by the various resources. This service provision spans, and requires interaction across three levels of maturity: (1) advanced networking R&D, (2) testbeds, (3) production services. It is the co-existence of these three levels, in unique combination in an open multi-domain environment, that constitutes a European communications commons and distinguishes the research and education networks from commercial service provision.
- The network itself must be made more 'intelligent' with sets of centralised services (such as visualisation services and collaborative tools) available through the NRENs.
- GÉANT 2020 should be considered as a substrate on which many (perhaps competing) services could be deployed, including services developed outside of the NREN community (e.g. by users, industry).

We envisage moving towards a richer mesh of networks based on ubiquitous virtualized resources. These mobile multi-cloud environments, where there is storage on every device, are much closer to the multi-domain nature of academic networking. Academic data centres will consolidate and reliance on global data centres will increase. New virtualized software-based approaches are arriving on the scene and more will come before 2020. In some situations video-conferencing and other 'low-level' services can also be very important.

NRENs should be encouraged to make business decisions. It will be up to the NREN community to decide what services to provide. The benchmark must always be whether the NRENs can add value over what is available for individual universities commercially, for example through coordination, resource sharing or sharing of best practice. Commercially available services should be used where appropriate but having regard to the functionality and service guarantees.

Focus. Focusing on cost-effectiveness and at the high-end on what does not exist commercially will enable the networks to strike the right balance between efficiency and innovation. A framework for accessing scientific data is an obvious example. The growth of digital repositories for permanent storage and preservation will require NRENs to provide federated AAI services on top of connectivity, an opportunity that is well beyond the capabilities of commercial operators.

Emphasise performance. The shift to services requires a greater emphasis on how the services are delivered and managed. Firstly, service delivery (in a multi-domain situation) raises issues regarding how to allow users to manage and control resources, avoiding hurdles by e.g. non-aligned security mechanisms at domain borders, while at the same time maintaining high performance. Indeed, getting components of such a system to work together is a significant operational challenge, creating an opportunity for performance services. Measurement of performance is not routine today but offers a major payback.

Maintain a chain of trust, security and privacy. As multiple cloud services are increasingly deployed, the GÉANT ecosystem should evolve towards supporting scalable and secure services, guaranteeing end-to-end quality to virtual R&E user communities having their own software-defined infrastructure. Moreover, protection against improper and criminal use, posing threats for individuals, institutions, nations and international organisations, is unavoidably going to be part of the world of research and education networking. All of this requires customized mechanisms for guaranteeing security and privacy in virtualised, federated environments. There are two levels for security and privacy. At the network management level, solutions must be developed, tested and standardized

for multi-domain network operations, monitoring and on-demand provisioning. At the user level, the focus is on establishing trust mechanisms and implementing user access control to resources distributed in a federated dynamic environment. These are real challenges for the GÉANT community. User access challenges, moreover, will become larger: On the one hand scientific data need to be open, but on the other hand increasingly trust mechanisms to safeguard privacy, integrity and property rights are required in ever more fields, not only in the medical sciences. Also the fast growing mobility of R&E users leads to more sophisticated user rules and extensions of secure roaming access control, as established in the Eduroam federation.

Grow beyond the network. A general purpose e-Infrastructure is more than just pipes. GÉANT 2020 must consider extending beyond the network to embrace other elements of the communication commons, such as clouds and data centres as the basis for scientific data repositories. This will close the gap and enable end-end quality. The energy and environmental agenda will be especially important here, as well as finding new models for a world of unlimited storage.

Support mobile networking solutions. Mobile solutions and services are an increasingly important element in the networking landscape and should be a key element of GÉANT 2020's user offer. Collaboration with commercial providers and industry will be essential.

3.2 SUPPORT THE GROWTH AND OPENING UP OF THE COMMUNITY

The goals for GÉANT 2020 here are threefold: close digital divides, open to the world and extend the user base.

3.2.1 Help to close digital divides

GÉANT 2020 is an instrument for inclusion in the creative knowledge economy. Inequities due to geographical location, income, work patterns (home versus laboratory) must be minimized, and where possible eliminated, striving to enable every scientist, researcher, entrepreneur and citizen to access data and resources on a fair basis.

Digital divides exist at many levels – global, national, city, campus, home – and exhibit self-similar (fractal) features. By 2020 digital divides in the context of international connectivity of European NRENs might not exist but geographical divides and national diversities will remain.

Removing digital divides is a prerequisite for Europe's economic and social development and a key objective of the Digital Agenda for 2010-15. Convergence in technology, unified integrated markets, and a common EU regulatory framework may help; but the addition of more nations in the eastern and south-eastern borders of the GÉANT service area will shift the problem elsewhere. The argument is no longer (in most cases) a matter of 'connectivity vs no-connectivity' but rather of quality and cost of access to networking and services.

Look for innovative policy solutions. The issue is closely related to market maturity, broadband penetration, availability of dark fibre, etc. Economies of scale come into play (it is cheaper to develop in the centre of the network rather than at the edges), making some routes expensive because of the solidarity inherent in supplying all providers within Europe. Since the underlying economics will not change within the next ten years, we must look for innovative policy solutions instead to achieve a comprehensive inclusion in the creative knowledge economy.

3.2.2 Hub to the world

The European dimension of the research networks has been important in terms of supporting access to knowledge and learning throughout Europe, helping to close digital divides, and enhancing Europe's position on the world stage. These aspects will continue to be important. But as scientific collaboration is becoming global, the attention will be shifting from local and European to global collaborations.

Europe must remain a major global hub for scientific expertise in all specialties and disciplines, and a partner of choice for global scientific collaborations. European researchers must have all the infrastructure required to participate in and lead major multilateral projects. World-class networking infrastructure including advanced services must be available to leverage partnerships around the world and maintain strong links with both developed and developing countries.

Work as a global partner. Success as a global scientific hub requires that Europe should remain active in providing links to all other continents; active in offering the most advanced networking services; and active in serving all major international research projects. There are important scientific instruments such as telescopes in other regions of the world used by the European researchers with the aid of the networks.

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. This calls for European and national contributions and resources to be brought together in an efficient manner.

Exploit scientific, cultural and historic links. In the global context, the European networks should continue to look to both developed and developing countries, aiming to make maximum use of Europe's existing linguistic, cultural and scientific links. The United States will remain a key player – both a partner and a rival – requiring concerted interaction. With their increasing significance in the global scientific effort, the BRIC countries will also require a stronger focus. Europe has a special relationship with many regions in

the world and is well placed to support these regions in building up their networking environments, such as Africa using both the EU's development aid and ICT budgets.

3.2.3 Extend the user base

GÉANT 2020 should continue to widen its user base, distinguishing between several constituencies. The traditional constituencies are:

- **The high-end users** in leading-edge scientific research. These will continue to impose the most demanding requirements and to provide a testing ground for new innovations and services.
- **The research and education community as a whole.** These have less demanding requirements in terms of bandwidth and storage and will be looking for cost-effectiveness as well as value-added services that allow their individual researchers and communities to work smarter and more efficiently, including outside of formal research and education settings. They are to be helped in navigating the foreseen future mesh of networks of virtualized resources.

The emerging constituencies are:

- Research and innovation resulting from the open science and innovation paradigms and spreading into SMEs, technology parks, including amateur scientists and innovators etc.
- There may be new users in sectors such as health, culture and public administration. Leveraging their scale and capacity for innovation, the European networks will be key drivers of public sector change, enabling service delivery and partnerships.

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. As the concepts of knowledge and learning grow wider and wider, it is essential that a close analysis is carried out on how to bring other relevant public services on board as well. Their requirements will be different in some areas and the strategy should be one of intelligent diversification.

With their high capacity and comprehensive coverage, the networks offer the economies of scale necessary to meet the increasing demands of the public sector (health, administration, schools, etc.). To date, partly imposed by national legislation, strategies in this area have been fragmented and the networks must find an effective and coherent approach to the opportunities to extend beyond their traditional user base.

Expansion should not inhibit the networks' main mission. While there are opportunities to aggregate smart internet users, this should not be at the expense of the leading edge. The networks must also be aware of the risk of being 'captured' by these new communities, many of which are much more powerful than the NRENs in user numbers or financial backing. A systematic joint European investigation into the related risks should start in order for the 2020 vision to be realizable.

3.3 PUSH THE STATE OF THE ART THROUGH INNOVATION

A much stronger orientation towards innovation is required, building on the networks' unique, but underutilized, position within the European innovation ecosystem. While the networks are already innovation hubs to a certain extent, the demands ahead are of a totally different order. Global collaboration, open innovation, rising user expectations, and a focus on new users and communities demand that NRENs move much more quickly in innovating to meet user needs. They effectively have to become living labs, providing live testbeds for future technologies and connecting researchers and others to the market. No commercial provider has this capability and it is a further demonstration of GÉANT's European scale.

The GÉANT ecosystem has numerous advantages for the competitiveness of the European ICT sector:

- The proximity to the research environment while at the same time operating as networks exposed to real rather than theoretical problems and issues.
- The multi-domain and co-operative nature, features which fit well with the open innovation and collaboration dynamic.

- The fact that they address very advanced needs well beyond market provision, which makes them natural breeding grounds for new solutions and services.
- The key role in mediating between the higher education sector and its suppliers in the provision of commercial networking services, including cloud services

Provide an influential research partner, testbed provider and lead customer for the European ICT industry. NRENs play a key role in mediating between the higher education sector and its suppliers in the provision of commercial networking services, including cloud services. Advanced networking testbeds are available in all industry sectors. NRENs should use pre-commercial procurement to foster innovation in technology and services within European industry.

Leverage buying power. Research networking is a major market for European industry, opening up important opportunities for the supply of technology and services. Universities are not interested in running

big IT hardware and infrastructure and increasingly are looking to use data centres elsewhere. NRENs are recognised as 'honest brokers' and can act as market influencers on behalf of the higher education community so as to ensure that universities get the quality and services they are looking for. Use of pre-commercial procurement will drive innovation by stimulating demand for advanced technology and services well ahead of commercial provision.

Provision of advanced testbeds through NRENs would facilitate innovation and the development of new products and services; possible regulatory implications need to be addressed here e.g. the use of pre-commercial testbeds on GÉANT infrastructures.

Drive networking breakthroughs. Without the stimulus provided by the publicly-funded networks, European industry would be deprived of an innovative lead customer and key investment partner. A recent US study²² notes that federally-funded R&D and academic networks, rather than private investments, are expected to drive networking breakthroughs.

²² PCAST (Dec 2010)

4 Reorganize for 2020

The recommendations in this Section address organisational aspects and other horizontal, cross-cutting issues supporting the three areas defined in Sections 3.1 - 3.3.

4.1 PREPARE FOR CHANGE

The organisation of the networks must adapt to reflect the new realities. The research and education networking environment is highly fluid, both technologically and commercially. Progress in networking is fast, commercial offers increasingly competitive, diversification in demand has gone hand in hand with technological diversity. Global coordination has, if anything, become even more a matter of many interlinked forums. Requirements of user communities are demanding and dynamic. New organisations and groups can be organised quickly around a particular project or service. GÉANT 2020 must reflect and respond to this dynamism.

The structure that is put in place for GÉANT 2020 must be able to address the three core functions:

- 1 community building, high-level strategy and co-ordination;
- 2 connectivity and services provision; and
- 3 innovation.

A federated model should evolve with flexibility and sustainability in mind. The federated model currently in place – which as we have noted is only one form of federation – has so far served Europe well. However, the future responsibilities of European-level organisations have to be defined more precisely with the following characteristics:

- Limited number of organizations and governance bodies with well defined and non-overlapping responsibilities and representations;
- Flexible, open and competitive approach to European and global connectivity;

- Advanced collaboration among the interested NRENs such as joint procurement, service provision, research collaboration, etc.
- European level organisations must have an ambition to take the leading role in global coordination forums;
- Execution of major innovation projects through consortia including NRENs, industry, users and academia with a dedicated management structure comprising the partners per project.

On the whole, a strengthening of innovation implies that NRENs, indeed, are brought closer to industry, while the stronger focus on services requires closer relationships with all users and communities. In short, simpler, more coherent, structures are needed. **The NRENs and their current European-level organisations themselves should come forward with proposals to meet these characteristics.**

NRENs should remain the key building blocks of this new structure. The national research & education networks are the bedrock on which all other structures are built. They create all other bodies and give the structure legitimacy since they are aggregators for their specific communities and interests. The situation in Europe will be increasingly diverse, especially in terms of international connectivity and GÉANT 2020 may not have the field to itself.

In some cases NRENs may wish to form clusters to meet some of their demands; NRENs must prepare themselves for these less centralised means of operating. Governments and the EU should support such cooperation too, as long as it is open and non-exclusive so as to get stronger building blocks within the GÉANT ecosystem.

Clarify mandates, governance and decision-making of European-level bodies. The GÉANT Experts Group recognizes the progress of European NRENs and

GÉANT over recent years and the key role of the NREN PC, DANTE and TERENA. It is however recommending that European NRENs try to consolidate their impact. European level bodies must have non-overlapping mandates along the three core functions defined at the beginning of Section 4. The bodies must also have clear decision-making mechanisms, rather than being just consultative.

In particular, the NRENs should try to find a means that would enable them to maintain structurally-separate, complementary mission-oriented bodies to sustain robust and advanced service delivery and boost innovation.

Open up innovation activities to a broader range of actors. Greater inclusiveness and transparency must be introduced, opening these activities up to industry, academia and user communities. A body like TERENA would be well positioned to organise a research and innovation platform for advanced networking activities. NRENs should be much more active in the existing and future European and global innovation forums, technology platforms, KICs etc.

4.2 ENSURE FLEXIBILITY IN TECHNOLOGY AND ARCHITECTURE

Allow for flexibility in architectural choices and operational modes, recognising the increasing diversity of solutions available. Networking technology continues to evolve rapidly; witness for instance the emergence of hybrid networking architectures, light path connectivity and Open Exchanges. Even if no major breakthroughs would occur in a 2020 time-frame, current technologies will continue to push the boundaries in terms of performance. Smart resource sharing, virtualization, ubiquity, mobility, security will all be in demand by the networks' disparate users. From an architectural point of view, there are several ways in which the networks might be configured; indeed, a key characteristic is the increasing diversity

of solutions available. The Future Internet is expected to be a complex federated architecture, providing multiple services tailored to co-existing, yet securely independent user communities. GÉANT has to grow as a European commons in an inherently multi-domain, open environment.

The guiding principles should be (1) what works best for users and meets their requirements, (2) what contributes to the European communications commons, and (3) what gives Europe the best position in global research and education networking.

Leverage existing investments while capitalising on new developments. In retrospect, the hybrid approach taken by several NRENs and the GÉANT backbone services proved to be the right one, offering great flexibility in how traffic is routed and managed. This approach remains valid and Europe should continue to extract the maximum returns from its existing investments. Demands for gigabit access will push this technology even further. By 2020 the European networks will require terabit backhauling together with multi 100-gigabit flexible lambda management across NREN territories and local domains. Advanced users will increasingly have the opportunity to create their own solutions on demand. GÉANT 2020 should follow international discussions in this area and pursue solutions to guarantee the best international connectivity, which will include IPv6 services for the majority of end users.

4.3 INTEGRATE EXPERIMENTATION, ENGAGE IN STANDARDISATION

Close the experimentation gap. The trend towards virtualisation, seen in all layers, requires testbeds as a basis for innovative applied research. GÉANT 2020 should support such testbeds. Leveraging Europe's investment in the Future Internet requires that we close the 'experimentation gap' by providing robust and reliable prototyping and validation environments.

This represents an opportunity for NRENs as infrastructure providers and innovation brokers. There is also potentially a wider role for GÉANT in the Future Internet ecosystem through involvement with the Future Internet PPP.

Engage actively in global cooperation for standardisation. The networking world is constantly defining standards to provide seamless international and global connectivity and services on top of that. Research and education networks, researchers in universities and research institutes as well as industry set de facto standards to which all major players adhere until new technologies and new standards arise. This is done in multiple bodies, and European networks should continue to play a very active role in these efforts also with a view to support European industry.

4.4 IMPROVE THE GOVERNANCE

Governance must be transparent and responsive. Such a complex ecosystem calls for governance structures that are transparent, streamline and responsive. Governance should reflect GÉANT's European dimension, with representation at national level being the main basis for the governance arrangements; but this does not mean that all Member States and all NRENs need to participate at every level. Re-thinking and focusing the activities currently undertaken by the NREN PC, DANTE and TERENA, as advocated above, would be particularly beneficial in terms of streamlining the governance arrangements.

Ensure a stronger role for users in governance of the networks. Greater user involvement in governance has long been considered and in several NRENs national institutions such as universities and research institutes are represented in some way. But appropriate solutions have yet to appear, especially involving large and well-organised user communities at a European level. Generic solutions will be difficult given the significant differences between communities as varied as high-energy physics, climate science, linguists, life sciences, etc. The two considerations here are:

- efficiency, especially for large projects which may need to be served by many NRENs; and

- how to balance the interests of the different (international) scientific communities within structures that are inherently national.

Nevertheless, it is essential that means are found to ensure users have a stronger voice in the running of the networks, including in overall planning and strategy. It should be clear who is the client and to whom the NRENs are accountable.

4.5 STEP UP FUNDING

As a common and strategic European infrastructure, the research networks should be publicly funded. As noted in Chapter 1, taking national and campus spending into account (using the 1:10:100 rule), Europe's total expenditure in this field is several billions per annum. This is a significant amount, though much smaller than the many billions spent on roads and other civil infrastructures. However, it is built up from very many small investments by universities, research institutes, regional and national governments. In addition, networks are often taken for granted. In many countries the need for continued investments to upgrade the networks and to run them, is insufficiently recognised. Just as roads and railways need to be maintained to keep them in good order and ensure the traffic flows, so e-infrastructures need to be upgraded, serviced and supported. In effect, the NRENs are the superhighways of the twenty-first century: we must not neglect them. The networks will not run themselves.

Europe's public funding of the research and education networks should be stepped up. In line with the vital importance of connectivity for the European Research Area, **the EU should fund the EU level research and education networking infrastructure in full**, with checks and balances as regards quality and need. In addition to this, we highlight the seven key recommendations:

- 1 **Member states must continue to invest in their research networks.** They are a vital part of the knowledge economy infrastructure and the costs are hard to allocate to separate users. However, while the diversity in the current national funding models should be retained, as a guiding

principle user influence should be increased. Institutions should pay a part of the true costs of the networks and services. Services beyond basic infrastructure should be funded by NREs, the EU and possibly other stakeholders.

- 2 GÉANT activities (operation, innovation, new services etc.)** (co-)funded by the EU should be supported by fewest possible mechanisms and concentrated in the RTD framework programme.
- 3 High-end users must bear a greater share of the burden.** Large European or international organisations and projects with exceptional communication requirements should realistically budget for full connectivity costs as part of their budgets and not expect from general infrastructure to meet their demands.
- 4 Budgets for innovation activities should increase significantly.** Innovation should be funded by the partners in the consortia and co-funded by the EU on a project basis.
- 5 Use the European Structural Funds in a more systematic way to address digital divide issues.** Since they rely to a large extent on national programming, the Structural Funds have been rather difficult for the research networks to access up to now and in general have not been seen as an appropriate instrument for international activities. This seems set to change, however, under moves to better align the Funds towards the EU2020 Strategy. Under such a regime, e-infrastructure should be a key element of their Structural Funds programmes. Explicitly basing operations on market terms and transparent real costs are important to justify subsidies.
- 6 Use Risk Sharing Financial Facility operated by the European Investment Bank.** With this mechanism the deployment of broadband networks could be financed. The research networks too could be facilitated by such loans, especially if through more explicit contributions of user institutions a continuous earning capacity is demonstrated.
- 7 Funding on all levels should be properly planned for and stable.** The vital role of this infrastructure requires that its funding is not sub-

ject to short term volatilities. It does not share the longevity and robustness characteristics of the vital civil infrastructures such as roads and water utilities.

4.6 UPDATE THE REGULATORY REGIME

In Europe the regulatory regime in relation to research and education networks has not kept pace with developments and needs to be updated in a number of areas:

Align the European regulatory frameworks to NREs potential. NREs' circumstances vary widely. Some are expanding the scope of their users (and are being encouraged to do so by their national authorities), whereas others are not allowed to do so under national legislation. The regulatory regime must present a coherent European view of the research and education networks.

Cut the costs of data roaming. Expensive data roaming within the commercial mobile networks is a big obstacle to the mobility of scientists and for other actors in the creative knowledge economy; these costs must come down. As noted above, GÉANT 2020 needs to be much more active in the wireless domain and the NREs may even wish to consider delivering such services themselves.

Reserve some spectrum for the research community. Certain wireless applications used by researchers will require dedicated spectrum. It will be important to dedicate part of the newly-available spectrum for the use of the research community (e.g. at 20MHz) as a way of ensuring Europe-wide connectivity and leveraging scientific data from the billions of sensors we will have in Europe by 2020.

Technically support mobility within the ERA. We must not forget that the European Research Area is made up of many thousands of individual students, scientists, researchers and innovators. Legislation and social services that facilitate the mobility and exchanges are being put in place. A European Researchers' Passport has been proposed as one such measure. GÉANT 2020 could and should provide the digital services related to all such mobility mechanisms.

Annex 1:

Terms of Reference and Panel Members

The GÉANT Expert Group (GEG) was charged by the European Commission's Directorate General for Information Society and Media to articulate "a 2020 vision for European Research and Education networking" and to identify an action plan for realising this vision.

Chair	
Žiga Turk	University of Ljubljana
Group Members	
Arndt Bode	Leibniz Supercomputing Centre (LRZ) and Technische Universität München (TUM)
Vasilis Maglaris	National Technical University of Athens (NTUA)
Dorte Olesen	Danish Technical University (DTU)
Roberto Saracco	Futures Centre, Telecom Italia
Peter Tindemans	Consultant, Euroscience board member
Pedro Veiga	Fundação para a Computação Científica Nacional (FCCN)
Rapporteur	
Michael Sharpe	MS Consulting & Research Ltd

Annex 2:

List of Consultees

The GÉANT Expert Group received evidence from the following individuals and organisations.

Marko	Bonač	ARNES (Slovenian NREN)
Didier	Bourse	Alcatel-Lucent
Istvan	Bozsoki	International Telecommunications Union
Alvis	Brazma	European Bioinformatics Institute
René	Buch	NORDUnet
Mário	Campolargo	European Commission
Dai	Davies	DANTE
Bob	Day	JANET (UK NREN)
Enis	Erkel	Turk Telecom
Remco	Frijling	Level 3 Communications, LLC
Mariano	Gago	Minister of Science, Technology and Higher Education, Portugal
Kostas	Glinos	European Commission
Yury	Grin	International Telecommunications Union
Frédéric	Hemmer	European Centre for Nuclear Research (CERN)
Gudmund	Høst	e-Infrastructures Reflection Group (eIRG)
Janne	Kanner	TERENA
Michiel	Kolman	Elsevier
Dave	Lambert	INTERNET2
Kees	Neggens	Surfnet (Netherlands NREN)
Frédéric	Noël	Grenoble –INP
Franz-Josef	Pschierer	CIO of the Free State of Bavaria and Vice-Minister of Finance
Malcom	Read	Joint Information Systems Committee (JISC, UK)
Vesa	Terava	European Commission
Klaus	Ullmann	DFN (German NREN)
Huib Jan	van Langevelde	Joint Institute for VLBI in Europe (JIVE)
Karel	Vietsch	TERENA
Peter	Wittenburg	Common Language Resources and Technology Infrastructure (CLARIN) initiative
Charles	Yun	Joint Institute for VLBI in Europe (JIVE)

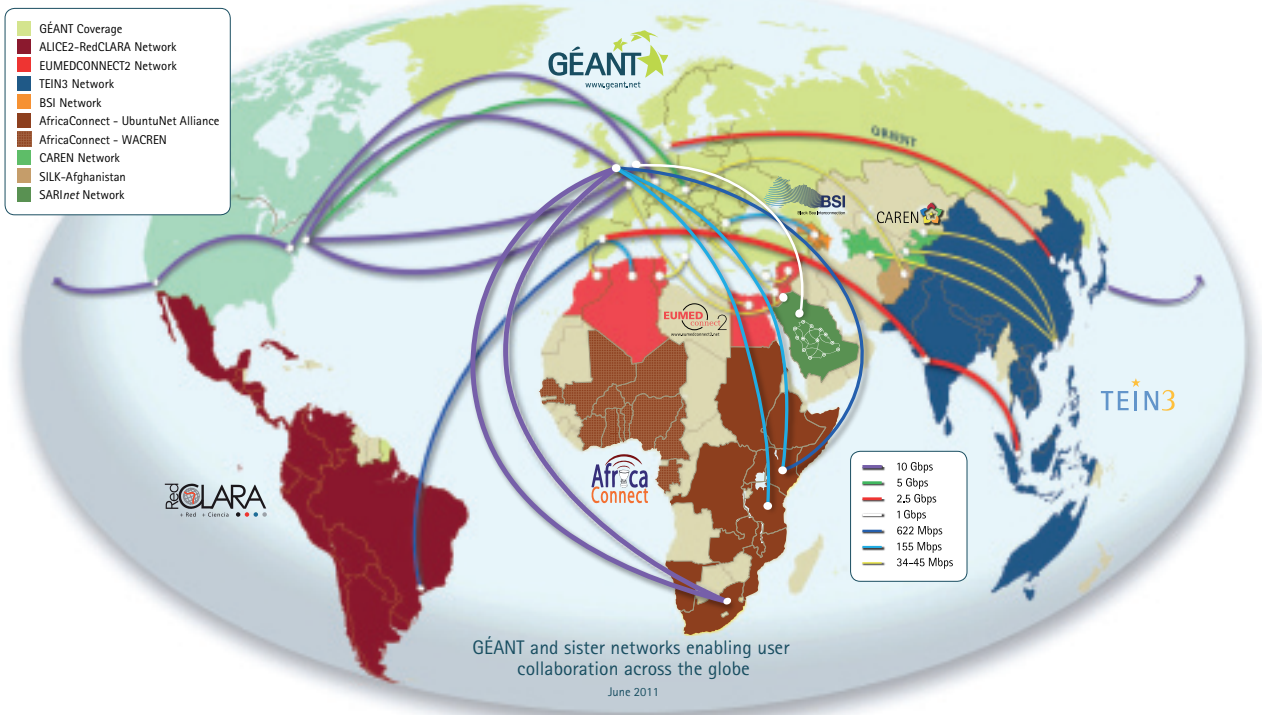
Annex 3:

List of Acronyms

AAI	authentication and authorization infrastructure
BoD	bandwidth-on-demand
CERN	Centre Européene pour la Recherche Nucléaire (European Centre for Nuclear Research)
CLARIN	Common Language Resources and Technology Infrastructure initiative
DANTE	Delivery of Advanced Network Technology to Europe
DWDM	dense wave division multiplexing
EBI	European Bioinformatics Institute
Eduroam	Education Roaming
eIRG	e-Infrastructure Reflection Group
ERA	European Research Area
ESFRI	European Strategy Forum on Research Infrastructures
eVLBI	electronic very long baseline interferometry
FIRE	Future Internet Research & Experimentation
GB	gigabyte
Gbps	gigabits per second
GÉANT	GÉANT, the high bandwidth pan-European network
ITER	International Thermonuclear Experimental Reactor
JIVE	Joint Institute for VLBI in Europe
KIC	Knowledge and Innovation Communities
LHC	Large Hadron Collider
MAN	metropolitan area network
MIMO	multiple-input and multiple-output
NREN	National Research and Education Network
NREN PC	NREN Programme Committee
PoP	point of presence
RAN	regional area network
R&E	research and education
SKA	Square Kilometre Array
TB	terabyte
TERENA	Trans-European Research and Education Networking Association



GÉANT At the Heart of Global Research Networking



connect • communicate • collaborate

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