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Research networks: global connectivity

As science becomes increasingly global and collaborative, researchers' dependence on fast and reliable data and communication links continues to grow. Research and Education (R&E) networks are designed to meet these demands, providing high-speed and reliable internet links to support applications and experiments crucial to research.

In the next decade, the demand for computationally driven data collection and information-sharing will escalate dramatically. GÉANT and other R&E networks will inevitably play a central role in enabling interconnectivity and collaboration across Europe and the world.

Enabling research and innovation

Networking is an essential part of the e-infrastructure connecting people around the world to global ICT services. Without reliable access to scientific instruments, data, collaborators, and other resources many international research experiments would not be possible.

Within Europe, the dedicated pan-European R&E network, GÉANT, transfers huge quantities of data (over 1,000 terabytes per day) for fields as diverse as radio-astronomy and drug research. In the past moving such large data-sets may have taken days or would not have been possible, but now with high-bandwidth technology, transmission can take seconds.



Neelie Kroes, Vice-President of the European Commission responsible for the Digital Agenda – *"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."*

Knowledge without borders

The GÉANT network is fundamental to the European Commission's vision of providing equal opportunities and access for European researchers irrespective of their location within Europe.

In October 2011, a report entitled 'Knowledge without Borders: GÉANT 2020' provided an action plan to serve the needs of the community and help maintain and strengthen Europe's research agenda. Among its recommendations were the provision of a more user-based service culture, and a continued commitment to increasing collaborations with other continents as well as testing emerging internet technologies.

Helping radio-astronomers see further back in time

Reliable and robust links also allow researchers to share data in real-time. Astronomers are using networks to connect multiple radio telescopes across Europe and beyond. Using a technique called e-VLBI, or real-time, electronic Very Long Baseline Interferometry, astronomers can inspect their results almost immediately. This technique relies on GÉANT and other networks to connect telescopes to a central data processor (a supercomputer), which correlates the data from the telescopes synchronously.

Exploiting e-infrastructures such as the GÉANT network, data can be streamed from each telescope and correlated in real-time. This updated technique yields results in a matter of hours, rather than the weeks it takes with the traditional technique of recording data to disk and physically shipping them for processing. The fast turnaround provides astronomers with a better tool for studying supernovae, gamma-ray bursts and other so-called transient activity that might otherwise be missed.



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The 'backbone of the internet'

Ultra-fast networks help to minimise the delays that build up as data is transmitted over the internet. The actual physical infrastructure (the network cables) no longer relies on copper cables but state-of-the-art optical fibres, which provide much more bandwidth and a reliable 'backbone' linking the major 'nodes' allowing researchers to collect, distribute and analyse data securely.



R&E networking in Europe is organised in a hierarchical fashion, connecting research and education community users. The network connection between two end users will be provided by a chain of several networks, each connected to the next. This chain will typically start with a campus network then may include a regional network before connecting to a national (NREN) network. Then to the pan-European backbone GÉANT, from there to another NREN and so on back down the chain to the user at the other end.

Together, GÉANT and the National Research & Education Networks (NREN) partners interconnect more than 40 million researchers and students at more than 8,000 institutions across 40 countries. Key routes on GÉANT already run at 40 Gb/s (gigabits per second), with planned upgrades to 100 Gb/s scheduled for 2012 to ensure the network remains ahead of user demand for bandwidth.



Kostas Glinos. Head of Unit "GÉANT & e-Infrastructure" in DG INFSO – the Directorate General for Information Society and Media. - *GÉANT needs to continue being ahead of the market in terms of the connectivity and services it provides to researchers; and it needs to organise itself to respond flexibly and efficiently to the needs of scientific communities for moving around extreme data volumes. GÉANT will help make Europe a hub of global e-Science.*

A global campus

e-infrastructures provide the ability for researchers to access a pool of resources (e.g. scientific instruments, data and collaborators) from anywhere ensuring equal opportunity for all researchers wherever they are located. It helps to bridge the 'Digital Divide' and ensure inclusivity. Seamless global connectivity allows virtual communities of researchers to co-operate and collaborate across continents as if they were on the same campus. As part of a larger consortium, individual NRENs can also benefit from long-term economy of scale.

Supporting 'Big Science' and everyday research

Research increasingly depends on large-scale databanks and massive processing power to help solve complex scientific or engineering problems. Any network performance issues can significantly impact scientists' ability to perform their research.

Users from a diverse number of academic disciplines rely on R&E networks including scholars in the arts and humanities. Biologists at the European Bioinformatics Institute (EBI) have utilised networks to share, store, manage and interpret bioinformatics data.

R&E networks have provided the foundation transport 'layer' for Grid infrastructures such as the Worldwide Large Hadron Collider Grid (WLCG). The 22 Petabytes of data generated from collisions at CERN is transferred and shared for analysis to 11 separate major computing centres dispersed around the world by high-speed optical fibre networking links.

Networks have also made an important contribution to speeding up the reconstruction of physical infrastructure after natural disasters. High-resolution satellite images sent for analysis for rescue teams via GÉANT and the Asia-Pacific TEIN3 network have helped plan rescues in the aftermath of earthquakes in China.



Torsten Reimer, Programme Manager (Digital Infrastructure), Joint Information Systems Committee (JISC) UK - *Today research is increasingly collaborative – across institutions but also countries and even continents – and it relies on ever growing amounts of data. In some research areas we are only beginning to understand the potential of this change, but collaborative access to data and digital infrastructure are now at the heart of research. Building and connecting research networks across and beyond Europe is critical to enable the potential of the digital transformation of research.*

Worldwide networking

In addition to its pan-European reach, the GÉANT network has extensive links to networks in other world regions including North America, Latin America, North Africa and the Middle East South, Africa and Kenya, the South Caucasus, Central Asia and the Asia-Pacific Region. Work is also on-going to connect to the Caribbean and to improve links to and within Southern and Eastern Africa.

Consequently GÉANT's extensive geographical reach provides Europe's NRENs with a gateway to NRENs worldwide, enabling European researchers to share huge quantities of data and collaborate effectively with their peers throughout the world. GÉANT is operated by DANTE (Delivery of Advanced Technology to Europe) on behalf of Europe's NRENs, who co-fund the project with the European Commission.

DANTE works closely with TERENA (The Trans-European Research and Education Networking Association), a collaborative forum that has supported and shaped the development of the internet for the last 25 years.



Fulvio Galeazzi, Project Manager, DECIDE - *The high speed Pan-European network GÉANT and other national research networks are focused on supplying connectivity and a growing portfolio of advanced services, allowing researchers to derive maximum benefit from a simple and secure access to a high capacity network. Dedicated network services for specific applications or projects, network performance monitoring tools, secure roaming services and authentication and authorization services for accessing shared resources (data and image archives, libraries, e-learning systems, etc.) are some of the innovative services available to the researchers.*

Sharing experiences

Experience and knowledge gained from R&E networking in Europe can help to advance e-infrastructure and innovation across other global regions. Advice, case studies as well as best practices in areas such as technical support, are assisting networking partners in other regions.

For developing countries, establishing an R&E network provides a framework for delivering on the United Nations anti-poverty Millennium Development Goals (health, climate, agriculture, education and the environment). It can also be one of the building blocks for creating an effective education system.

Researchers in Sub-Saharan Africa from early 2012 will be connected to international networks via the AfricaConnect project. It is expected that many research areas will advance through the high-speed connectivity and supplementary services provided by networking.

In the remote parts of Africa, researchers can benefit from distance learning and live videoconferencing, enhancing skills and knowledge in the local research community, thus unlocking Africa's intellectual potential.

In South Africa, e-Health and telemedicine, astronomy and physics are already actively exploiting the high-performance network infrastructure.



Domenico Vicinanza, Project Support Officer, DANTE - *From a network management perspective, R&E networks provide new standards of clarity and control. You can monitor use of resources in real time and rely on network repair, maintenance and development activities being managed centrally, with 24-hour central support. R&E networks offer tomorrow's network today."*



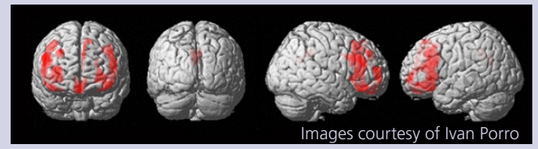
Peter Clarke, Professor of Physics at the University of Edinburgh UK - *R&E networking is vital to the Large Hadron Collider (LHC) operations. We transmit many Petabytes of data each year to be reconstructed and analysed in computing centres around the world. Without our NRENs and GÉANT we wouldn't be able to produce the results you see from the LHC.*

Guiding technological innovation

R&E networks offer opportunities for experimentation and are established pioneers in the use of advanced network applications and emerging internet technologies. By facilitating the development – from idea, to prototype, to the commercial internet – many technologies and applications find their way from research networks to the commercial world.

Assisting early diagnosis of Alzheimer's

Rapid, easy and secure access to networks is also important in healthcare. Clinicians often require access to large medical reference databases in order to compare patient imaging data for making an informed diagnosis, which is especially important for the early diagnosis of Alzheimer's.



Images courtesy of Ivan Porro

The DECIDE (Diagnostic Enhancement of Confidence by an International Distributed Environment) project uses high-speed research links to provide doctors with an easy-to-use online application for the analysis of neurological data (i.e. brain scans). The network and processing power to carry out such analysis is effectively beyond the budgets and computing power of most hospitals. R&E networks provide connectivity to hospitals and national research networks, allowing doctors to access and upload biomedical images irrespective of location, in order to collaborate and better understand the disease process.



Richard Hughes-Jones, Technical Customer Support Manager, DANTE - *"To improve the way we deal with disease, disasters and other natural challenges, we need to understand more about our world - how it works and how it's changing. If we're going to make life better for people, we have to learn to share our knowledge and our skills. The answer lies in working together effectively. R&E networking is important because it provides a platform that enables better cooperation, collaboration and integration within and between geographically dispersed research and education communities."*

User-focussed and flexible service

In addition to high-speed internet access, users benefit from a number of services provided by international R&E networks from large file transfers, computer modelling and simulations, application sharing and a whole host of visualisation tools.

However, research communities differ in their requirements, so flexibility and scalability are increasingly being built into services. For example, LHC physicists may need increased access to large volumes of data for relatively short periods of time.

GÉANT's perfSONAR MDM is a multi-domain monitoring tool that makes it easier to simplify troubleshooting and access performance problems occurring between sites connected through several networks.

Bandwidth-on-demand is expected to be valuable to users who may need to transport high volumes of data over the network in relatively short time periods. It allows users to reserve end-to-end data transport capacity when they need it, between end points participating in the service.

Future challenges

Big challenges lie ahead for R&E networking; not only will the networking consortiums have to meet the needs of supporting large scale computing but there are a number of organisational and technical hurdles to overcome.

- **Increasing capacity** by moving from 10-Gb/s to 40-Gb/s and 100-Gb/s line speeds.
- **Providing 'greener' networks** by carrying out environmental impact studies to formulate best practices across the infrastructure.
- **Safeguarding and addressing security (privacy and anonymity) issues.** As capacities increase and global connectivity advances, it will be increasingly important to develop an integrated security framework in order to safeguard against cyber-attacks. GÉANT employs an automated system - the National Security Handling and Response Process (NSHaRP). The system not only informs affected users of threats but also provides support for dealing with security incidents.
- **Moving towards interoperability** - The Open Grid Forum (OGF) is leading the global standardisation effort and interoperability between the different technologies used in distributed computing systems around the world. Their Network Services Interface (NSI) protocol will provide an interface between network domains in order to provide interoperability in a heterogeneous multi-domain environment.
- **Ensuring governance is transparent and inclusive** - Streamlining the governance arrangements to reflect the European and international dimensions, and allowing users more of a role in the development of governance activities.
- **Cutting the costs of data roaming.** Expensive data roaming within the commercial mobile networks is a big obstacle to the mobility of scientists.

Switching over: IPv4 to IPv6

The phenomenal global growth of the internet has led to a shortage of internet addresses – the numerical label assigned to each device. IPv6 is the new version of the internet address protocol that has been developed to supplement (and eventually replace) IPv4, the version that underpins the internet today. The switch to IPv6 has been validated and certified prior to wider release by GÉANT and many European NRENs.

Bringing to life ancient instruments

Reconstructing the sounds of ancient musical instruments has become a reality for archaeologists through the ASTRA (Ancient instruments Sound/ Timbre Reconstruction Application) project which has been facilitated by high-speed transatlantic internet links. A technique called physical modelling synthesis, was used to reconstruct two South American instruments – a Chilean drum and a Peruvian flute – which had not been played for over a thousand-years.



Video - excerpt of a concert - www.astraproject.org/download.html

Archaeological data (e.g. fragments from excavations, written descriptions, pictures of the two instruments) were sent through the ALICE2 transatlantic link between Europe and Latin America. Several gigabytes of data were exchanged in almost real-time by two teams of researchers in the two continents. To speed up the procedure and achieve the necessary processing power, the reconstruction processes were run simultaneously on hundreds of computers throughout Europe and the lower Mediterranean (using the European Grid Infrastructure, GILDA and EUMEDGRID). The sounds were transferred back to Santiago in Chile, to be played for the first time at a public performance of an opera.

For more information:

TERENA: ***www.terena.org***
DANTE: ***www.dante.net***
GÉANT: ***www.geant.net***
TEIN3: ***www.tein3.net***
RedCLARA: ***www.redclara.net***
SURFNet ***www.surfnet.nl/en/***
CAREN: ***http://caren.dante.net***
Internet2: ***www.internet2.edu***
AfricaConnect: ***www.africaconnect.eu***
DECIDE: ***http://www.eu-decide.eu***
ASTRA: ***www.astraproject.org***
Knowledge without Borders: ***http://cordis.europa.eu/fp7/ict/e-infrastructure/docs/geg-report.pdf***
GÉANT Real time Monitor (RTM) ***http://rtm.hep.ph.ic.ac.uk/net_webstart.php***
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