Research and Education Networks around the World and their Use

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Summary

Research and education is an increasingly global activity with collaborations involving partners across multiple countries and world regions. Research and Education Networks provide the necessary connectivity to enable these collaborations to function efficiently and successfully.

National Research and Education Networks (NRENs) have been established in over 100 countries around the world. In most world regions, the national networks are interconnected by a regional network which in turn connects to its counterpart networks in other world regions. This provides a mesh of interconnected networks which provides the necessary connectivity for researchers and educators across the world.

This paper will describe the Regional Research and Education Networks and will demonstrate their importance by exemplifying global projects in numerous fields including high energy physics, radio astronomy, health and the biomedical sciences, earth observation, the environment, education and the arts. The paper will also give a brief summary of the number of EC-funded projects which currently have Latin American partners, and finally will provide a summary of the distinct ways in which Research and Education Networks can benefit academics and their multinational research or education projects.

Key Words

Research and Education Networks; European Commission; GÉANT; RedCLARA, C@ribNET; CKLN; Internet2; ESnet; NLR; NISN; EUMEDCONNECT3; UbuntuNet Alliance; AfricaConnect; CAREN; TEIN3; TEIN4; Latin America; North America; Caribbean; Europe; Northern Africa; Middle East; Southern and Eastern Africa; Southern Caucasus; Central Asia; high energy physics; astronomy; health; biomedical sciences; earth observation; environment; education; arts;

1 Research and Education Networks: providing connectivity for the research and education community across the globe

Research and education is an increasingly global activity. Projects and collaborations often involve partners in multiple countries and world regions. The ability to communicate effectively and to share data quickly and reliably is often essential for their success.

Today, National Research and Education Networks (NRENs) exist in over 100 countries across the globe. Connectivity between the NRENs is typically provided by regional research and education networks, such as GÉANT in Europe and RedCLARA in Latin America.

In addition to providing IP connectivity, national and regional networks provide additional services including advanced connectivity services such as point-to-point connectivity or bandwidth-on-demand, network monitoring services such as perfSONAR, or identity federations and the ability to access the network when away from the home institution through eduroam®. In recognition of the need for such services to cross national and regional barriers, collaborative efforts are made by NRENs and regional networks to ensure the interoperability of their services and to extend them to an ever greater number of end users.

1.1 GÉANT, the European Research and Education Network

GÉANT is a continuation of the success story of the European Research and Education network which today is in its seventh generation. Connecting a total of 40 European countries through 36 National Research and Education Networks, GÉANT benefits a total of 40 million users across the region. The topology of the GÉANT network can be viewed in Figure 1 below.

The length of the GÉANT infrastructure totals 50,000km, including 12,000km of lit fibre which can be configured at speeds of tens of Gbps at present according to demand. Current work to upgrade the network will provide the ability within the next year to light the network at speeds of up to 100 Gbps.

For users with high bandwidth requirements, GÉANT's lit fibre network enables dedicated point-to-point circuits of between 155 Mbps and 10 Gbps to be implemented. In addition, bandwidth-on-demand connectivity is also available for users with occasional high bandwidth requirements.

GÉANT is also a world leader in providing services which benefit end users in a variety of ways:

The networking monitoring tool, perfSONAR MDM, is deployed across the network enabling networking engineers to identify performance issues and effect a solution in a timely fashion. Interoperability with the North American flavour of perfSONAR also means that network monitoring can extend beyond GÉANT to its North American partners.

Through the eduGAIN service, services offered by NRENs within the GÉANT community can be made available to users across Europe who are registered with a local federation. Equally when travelling to a different institution, eduGAIN enables users to access their usual services as if they were still at their home institution.

The global eduroam® service provides secure roaming connectivity to users at hundreds of participating institutions across Europe and beyond, including universities, libraries and research institutes.

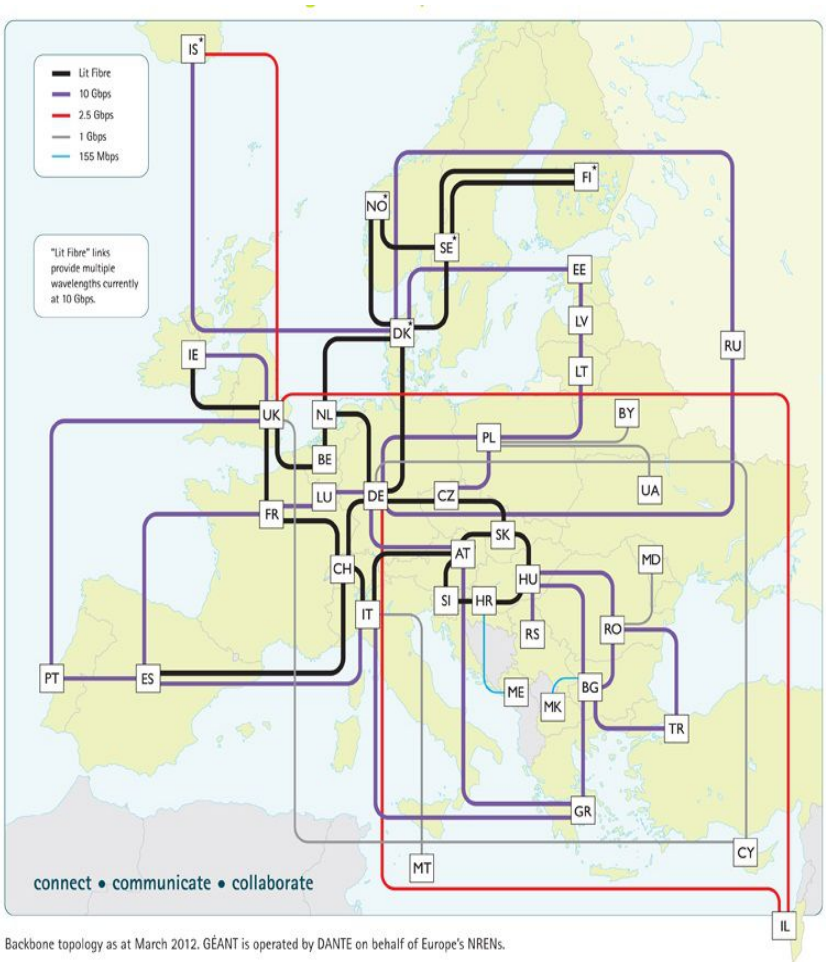

Fig. 1. The GÉANT Backbone topography as at March 2012.

1.2 Research and Education Networks around the World

Beyond Europe, the number of countries with internationally connected National Research and Education Networks continues to grow. At the time of writing the figure stands at 62. In most world regions, international capacity is provided by regional networks such as RedCLARA in Latin America which provide onward connectivity to other world regions. At the heart of this mesh of networks is GÉANT which in many cases enables one world region to connect with another, e.g. RedCLARA connects to the Southern and Eastern African network, UbuntuNet, via the GÉANT network.

The map in Figure 2 shows the world regional research and education networks and how they connect to GÉANT.

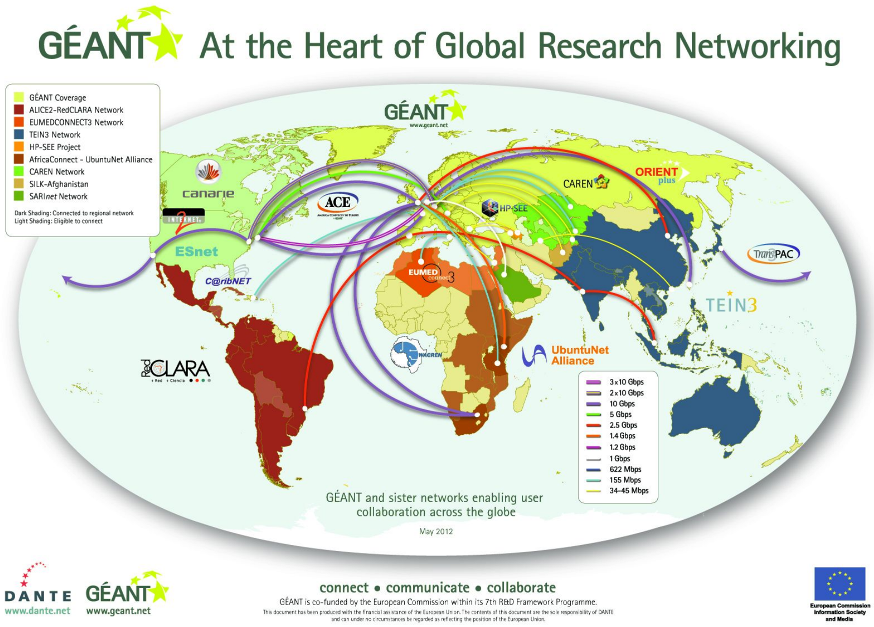

Fig. 2. The GÉANT Global Connectivity Map: GÉANT at the Heart of Global Research Networking.

The Latin America research and education community is provided for by the RedCLARA network which today interconnects 13 Latin American NRENs, with a further five NRENs eligible to connect. RedCLARA connects to Europe via a 2.5-Gbps link between Sao Paulo and Madrid. The RedCLARA network was established in 2003 under the European Commission-funded ALICE (America Latina Interconectada con Europa) project, and continues to receive EC funding through the successor ALICE2 project until the beginning of 2013.

The North American research networking environment is more diverse than in Europe and other world regions, with research networking connectivity provided by CANARIE in Canada, and four main research and education networks in the USA: ESnet, Internet2, National LambdaRail (NLR) and the NASA Integrated Services Network (NISN). Both IP and point-to-point connectivity between Europe and North America is available on multiple 10-Gbps links with a total capacity of 85 Gbps.

C@ribNET, the Caribbean R&E Network run by the Caribbean Knowledge and Learning Network (CKLN), was established in 2012. With EC funding made available to CKLN via the World Bank, C@ribNET today interconnects a total of 13 Caribbean countries to each other and to the European R&E community with a 155-Mbps link between Santo Domingo and Paris. The Caribbean is also connected to RedCLARA in Latin America at 45 Mbps and to the research and education community in North America at 300 Mbps. A second implementation phase will see a further eight Caribbean countries being connected to C@ribNET.

R&E connectivity for North Africa and the Middle East is provided by the EUMEDCONNECT3 network. With nine beneficiary countries, EUMEDCONNECT3 currently connects the Algerian and Palestinian NRENs to GÉANT and to each other. Concerted efforts are being made to re-establish connections to other countries in the region.

The UbuntuNet Alliance is a regional association of National Research and Education Networks (NRENs) in **Southern and Eastern Africa.** It was established in the latter half of 2005 by five established and emerging NRENs and now has a total of 13 NREN members. Currently four of the UbuntuNet Alliance Member NRENs have international connectivity via an UbuntuNet traffic exchange point in London, where UbuntuNet also connects to GÉANT. The EC-funded AfricaConnect Project which began in 2011 aims to expand capacity within the region, enabling more Sub-Saharan African countries to join the UbuntuNet network, creating traffic exchange points within the region and increasing capacity to Europe.

In the South Caucasus region, the EC-funded HP-See Project provides international connectivity for the Azerbaijani and Armenian NRENs.

The EC-funded Central Asian network, CAREN, provides international R&E connectivity for a total of four countries in the region (Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan). Uzbekistan is also eligible to join the CAREN project.

In Afghanistan a total of nine sites are connected to the GÉANT network via a satellite link through the NATO-led SILK Afghanistan initiative

NRENs in the Asia-Pacific region are interconnected by the EC-funded TEIN3 project which provides intraregional connectivity as well as a 2.5-Gbps link to GÉANT. The 19 networks connected to TEIN3 also benefit from an additional 2.5-Gbps link to GÉANT provided by the EC-funded ORIENTPlus project.

2 Global Collaboration Using R&E Networking Infrastructure

The ways in which Research and Education Networks can benefit global collaborations and projects are varied. In addition, the subject matter of the projects which are supported by R&E connectivity are extremely diverse. The following paragraphs set out some examples of the different projects which use the networks and how they benefit from them.

2.1 Radio Astronomy

Every day radio telescopes such as the European Southern Observatory in Chile collect large amounts of data which need to be transmitted to a central data processor, such as JIVE, the Joint Institute for Very Long Baseline Interferometry in Europe. Here they can be correlated with the data of simultaneous observations made by other radio telescopes around Europe and the rest of the world to form very sharp, high-definition images of cosmic radio sources. Data was previously collected at each telescope on magnetic tapes and later onto hard disk. These physical media were transported by courier, taking several days. By harnessing the benefits of Research and Education Networks, the data can now be transmitted from the telescopes to the central computer in just seconds, enabling astronomers to create real-time views of the outer reaches of the universe much more quickly and efficiently.

Fig. 3. Research and education networks enable data from radio telescopes to be transmitted to data correlation centres in seconds, saving the cost and time to ship the data on disks or hard drives.

2.3 e-Health and the Biomedical Sciences

The DECIDE project is an example of how biomedical science projects can harness the benefits of Research and Education Networks. Over 35 million people currently suffer from a form of dementia, such as Alzheimer's. With no current cure, the medical focus is on earlier diagnosis, which dramatically improves the quality of life for patients and their carers.

However early diagnosis can be difficult and accurate identification requires analysis of a rapidly increasing volume of patient data, particularly detailed medical scans. The network and processing power to carry out this analysis effectively is beyond the budgets and computing power of most hospitals.

The Diagnostic Enhancement of Confidence by an International Distributed Environment (DECIDE) project aims to solve this issue, by creating a simple, secure and easy to use diagnostic tool, accessible by any doctor. It achieves this by bringing together the power of research networks, such as GÉANT, distributed databases, grid computing and powerful diagnostic algorithms. The combination of high speed networks and the distributed processing power of grid infrastructure mean that hospitals do not need to invest in any additional computing resources. Doctors simply log onto DECIDE from any networked PC, upload their patient's biomedical images and let DECIDE handle the processing, comparing the images with vast reference databases and quickly returning the results to aid faster diagnosis, and consequently better patient care.

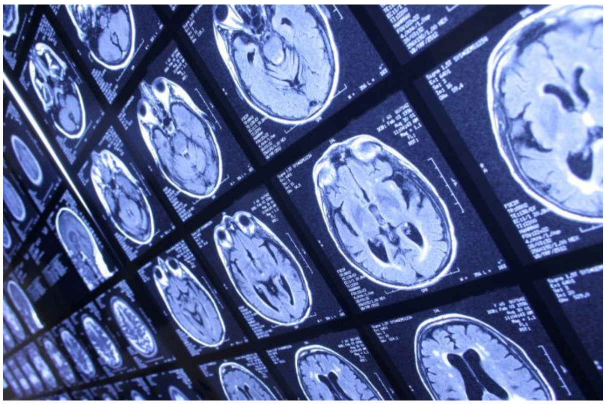

Fig. 4. Research and Education networks support the DECIDE Project, providing a tool to help doctors in the diagnosis of patients with illnesses such as Alzheimer's.

Research and Education Networks can also assist in the diagnosis of patients by reducing the distance between medical experts and patients through telemedicine. Providing fast access to specialists can make the difference between life or death, but previously could be difficult because of the distance between a patient's home and the major hospital that the doctor was based in, particularly in the developing world. The advent of technology such as telemedicine removes the need for travel, enabling diagnoses or second opinions to be delivered through videoconferencing and the sharing of patient data. This has the potential to dramatically improve healthcare across the globe.

2.4 Earth Observation

Satellites are used to gather vast amounts of earth observation data and transmit them to download stations on the ground. From here the data need to be transmitted to centres where they are processed.

Marine pollution, such as oil spills, is of significant environmental concern. However, the sheer size of the seas combined with the amount of shipping on them makes it extremely for authorities to identify polluters and collect evidence against them.

However, data collected by satellite on oil spills can, if distributed quickly enough after reaching receiver stations, enable authorities to react within a sufficient time window to limit the environmental impact, and provide evidence against to prosecute the polluters.

Due to the quantity and size of the images produced by satellites, the high bandwidth and reliability of Research and Education Networks is essential in ensuring that the data is transmitted from the download station to the processing centre in a timely fashion.

2.5 The Environment

The use of information and communication technologies (ICT) is an omnipresent part of modern-day life and the economy. However, it is often forgotten that ICT depends heavily on energy typically generated from fossil fuels, meaning that ICT has a significant impact on the environment. Data centres are particularly demanding in terms of energy.

If data centres can be powered by renewable energy sources, then their environmental impact can be significantly improved. However, renewable energy sources such as solar or wind power are typically unreliable, meaning that it is not possible to rely on any one data centre at a time.

However, a collaboration between Europe and Canada, supported by research and education network infrastructure, has started to show that by combining green data centres or nodes into a cloud-based model that monitors usage and energy availability at the different nodes, it is possible to migrate workloads between nodes in line with demand and the available green energy supplies.

Fig. 5. Reducing the environmental impact of ICT infrastructure by enabling greater use of renewable energy is the aim of the GreenStar Network project.

2.6 Education

In the field of education, Research and Education Networks can benefit knowledge-sharing among experts and students by underpinning collaboration tools such as high-quality videoconferencing.

In 2009 a project was started which aimed at bringing together experts in the field of artificial intelligence with students interested in the subject from across the globe.

Known as the ShanghAI Lectures, the project involves an annual series of lectures given from a number of locations around the world to students in many different nations.

Fig. 6. The ShanghAI Lectures bring AI experts and students together across Research and Education Networks.

The ShanghAI Lectures use advanced methods of knowledge transfer that go beyond traditional e-learning methods. Through interactive videoconference lectures and a wide range of web-based collaborative resources the programme enables participants to learn, work together and share their knowledge. Resources include powerful robotics simulator software as well as lecture slides, exercises, lecture recordings, forums and video galleries.

Over the last three years more than 1000 participants from over 40 universities on 5 continents have been part of the programme, with 2011 seeing students and researchers from 25 countries and 16 universities take part in videoconferences.

2.7 The Arts

The epigonion and barbiton are two Ancient Greek stringed instruments which for many centuries have not been heard, until now. Using data-intensive digital modelling enabled by power of grid computing supported by Research and Education Networks in Europe, it has been possible for the sound of these instruments to be digitally recreated, and played using an electronic keyboard in public performances. This work, carried out through the ASTRA project, has also been extended to recreate the sounds of two Latin American instruments, the flute-like *quena de hueso* from Peru, and a drum-like instrument from Chile.

Research methods into understanding the activity of volcanoes, so that it may one day be possible to reliably predict eruptions, are many and varied. One method known as data sonification turns seismic graphs into audio files by converting the peaks, troughs and contours of the seismic waves into audible musical notes. The aim is to enable researchers to use their hearing to identify specific patterns in the seismic activity. This work is compute-intensive and requires the support of grid-computing powered by research and education networks. Having produced “volcano melodies”, musicians have taken these melodies to compose “volcano music” which has in turn inspired a dance performance entitled “Volcano Dance” performed at the Kennedy Center of Performing Arts in Washington, DC.

Fig. 7. Volcano Dance, performed by CityDance Ensemble at the Kennedy Center of Performing Arts, Washington, DC, to music created from sonified seismic data.

In the world of music, bringing performers together for rehearsal can be time-consuming and costly. However, researchers in Italy have identified a method to reduce the need for performers to travel by enabling them to play together as if they were in the same room, though they may actually be separated by significant distances. The Low Latency (LOLA) software reduces the time taken between a sound being produced and it being transmitted across the network to a minimum, meaning that the time delay between one performer producing a note and the other performer hearing it is less than the human brain can perceive. To succeed, LOLA requires the high-bandwidth point-to-point connectivity provided by Research and Education Networks.

2.1 High Energy Physics

High energy (or particle) physics studies the elementary particles that make up ourselves and the universe around us, focusing on subatomic particles and the interactions between them. As many of these elementary particles are only created through high energy collisions between other particles, experiments, such as CERN’s Large Hadron Collider (LHC), require vast amounts of infrastructure in order to operate.

The information produced by these experiments is enormous – the Large Hadron Collider is the world’s largest ever scientific experiment and produces 22 petabytes of data per year. Collaboration among scientists around the globe is essential for the analysis and understanding of these vast amounts of data. Sharing this information quickly and securely is imperative to enable this scientific progress.

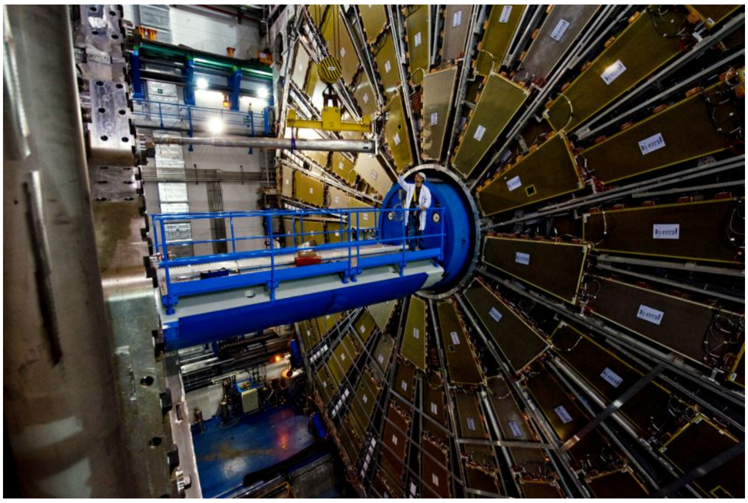

Fig. 3. High-energy physics experiments require vast infrastructures and produce enormous amounts of data.

To access, analyse and process this data requires new ways of working. It would be impossible for a single location to process all the results of an experiment such as the LHC, meaning it needs to be shared amongst a network of computers across the globe, with researchers working together to analyse and share their results.

Distributing and processing the outputs of high energy physics experiments and then sharing the results requires a truly global collaboration, and would be impossible without research and education networks. The guaranteed high capacity and high speeds needed to transmit these huge amounts of data cannot be provided cost-effectively by the commercial internet. Consequently advanced research networks such as GÉANT are central to high energy physics, delivering the secure and reliable performance necessary for experiments to operate and share data amongst scientists.

3 Latin American Involvement in EC-funded Projects

In 2009 an analysis of projects funded by the European Commission's Framework Programme 7 identified that just over 100 projects involved participants from Latin American. A similar analysis in 2012 has identified almost double that figure, with a total of 187 projects involving partners based in Latin America. A further analysis revealed that Latin American universities or institutions represented at TICAL2012 were involved in some of those projects, covering the following themes: renewable energy, climate change and the environment; biomedical sciences; informatics; livestock; food; fuels; nanostructures; particle physics; poverty; astronomy. Further information on this analysis can be obtained by contacting the author.

4 Summary

This paper has demonstrated that there is a wide variety of collaboration methods which enable researchers and educators successfully implement their projects, from the transfer of large quantities of data, the storage of data and access to it, grid computing and videoconferencing. These collaboration methods typically require high bandwidth and the reliability which can only be provided by Research and Education Networks.

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