« networking the networkers »

TERENA COMPENDIUM

of National Research and Education Networks in Europe

2011 Edition

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Editor: Bert van Pinxteren
Text, tables and graphs: Bert van Pinxteren, Marc van der Holst
Database and website: Christian Gijtenbeek, Dick Visser
Proofreading and correction: Rob Stuart, LocuMotio.nl
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For further information or to place an order, please contact:
TERENA Secretariat
Singel 468 D
1017 AW Amsterdam, Netherlands
Email: **secretariat@terena.org**

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INTRODUCTION

In more than ten years since its inception, the TERENA *Compendium* has grown into a much sought-after and authoritative reference source for researchers and organisations who are interested in the development of research and education networking. With each successive edition, the information contained in the *Compendium* has become increasingly varied and dependable, although, as always, the data should be interpreted with the necessary caution.

This year's edition, the third to be published as part of the GN3 (GÉANT) project, has been enhanced with input from activity leaders working in that project. New this year is that in most cases, all GÉANT partner NRENs are grouped together. As in previous years, we have attempted to examine and partially explain multi-year or 'longitudinal' trends. Summaries and analyses of the most important information are presented in 'overview' subsections at the start of each section.

The **Key findings** section that follows this introduction provides a more general analysis of recent developments.

Production of this edition was overseen by the Review Panel: Tryfon Chiotis (GRNET), Lars Fischer (NORDUnet), András Kovács (HUNGARNET), Thomas Lenggenhager (SWITCH) and Mike Norris (HEAnet).

For this edition, the survey questions were simplified. As before, NRENs from outside Europe were invited to submit their data. The responses cover a total of 58 NRENs from the same number of countries (45 from Europe and the Mediterranean region; 13 from other parts of the world). All the NRENs were asked to double-check their responses and ensure that the information was up to date.

In general, this edition of the *Compendium* looks back over five years, comparing 2011 with 2007. It offers the most extensive overview of NREN services yet, including security services, network collaboration tools, network computing resources and e-learning.

Collecting such data requires contributions from, and careful checking by, several staff members of each NREN. TERENA would like to thank all those in the NREN community who gathered, submitted, clarified and checked the data included in this publication.

The *Compendium* consists of two parts: the information submitted by the individual NRENs (available in full at **www.terena.org/activities/compendium**) and this publication. Most of the tables and graphs first list all the responses from the GÉANT partner NRENs and then those from other countries. The data are usually presented in alphabetical order, sorted on the English name of each country. All the European NRENs included in the *Compendium* are listed in Section 1.1. NRENs in all other parts of the world are listed in Section 1.2. In several tables, the responses as received from the NRENs were edited and abridged. The full responses are always available online.

Please note that, unless otherwise specified, the data indicate the situation on or around 31 January 2011.

We hope that this eleventh edition of the *Compendium* will prove to be at least as valuable as the previous ones. You are warmly invited to give feedback, which is the key to the *Compendium's* future development!

Bert van Pinxteren
TERENA

KEY FINDINGS: A BRIEF OVERVIEW

Networking to services

The Internet basically began as a technological innovation for which growing numbers of institutions and individuals found an ever-increasing variety of uses. Subsequent Internet developments were essentially driven by further technological innovations. Currently, the emphasis on technology is decreasing and greater importance is being attached to meeting user demands. This does not mean that the technology is no longer developing; it does mean that, more so than in the past, developments in services and technology have to go hand in hand. Furthermore, it is becoming increasingly important to disseminate information about these services and technologies. This edition of the *Compendium* offers the most extensive overview of NREN services yet, including security services, network collaboration tools, network computing resources and e-learning.

In her foreword to the recent GÉANT Expert Group report, Neelie Kroes, European Commission Vice-President for the Digital Agenda, writes:

> *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.*[1]

New and advanced services

Because many NRENs have excellent technical expertise and maintain close contacts with the user community, they have been able to develop high-end services that are currently not available, or not affordably available, from commercial Internet Service Providers (ISPs).[2]

- A case in point is the Identity Federation, a 'meta-service' developed by NRENs and their communities. Almost all GÉANT partner NRENs currently provide an **Authentication and Authorisation Infrastructure** (AAI) or are planning to do this. In most cases, the web single sign-on federation is operated by the NREN. Most of the GÉANT partner NRENs (and a few other NRENs) are planning to join the new **eduGAIN interfederation service**.

- The development of AAI enables new services. Thus, nine GÉANT partner NRENs currently offer a platform of bundled **services for collaborative groups** of users, eight more are planning to introduce this. In most cases, these services are federated, allowing access to them through a web-based authentication scheme.

- Seventeen GÉANT partner NRENs currently provide a **multimedia content repository** and nine more are planning to establish one. Over the past year, a number of NRENs have introduced user-initiated live streaming support. Such repositories increasingly support standards-based metadata exchange technologies, which enable a 'web' of NREN and other related repositories to be created. There is scope for considerable growth in this area.

- **National computing services** have become an important area for NRENs. The data show that in more than half of the GÉANT partner countries there is a national computing service. In an additional 9% of the countries there are plans to set up such a service. In one-third of the countries the national computing service is operated by the NREN.

- Seven of the GÉANT partner NRENs currently offer virtualisation services; fourteen others are planning to introduce them.

New technologies and increased traffic

New and intelligent services and research activities require new technologies, new approaches and high-speed networks. The continuing developments in services and technologies are closely interrelated and interdependent. Many

[1] *Knowledge without Borders, Report of the GÉANT Expert Group*, Luxembourg, October 2011 (ISBN 978-92-79-21036-5)

[2] For further information, see John Dyer, *The Case for NRENs* (2009), available at www.terena.org/publications/files/20090127-case-for-nrens.pdf

NRENs have made substantial progress towards deploying hybrid IP-optical networks and offering the associated end-to-end services.

- Congestion at the backbone and external connection levels seems to have been largely resolved for the time being; in GÉANT partner countries, average congestion at the campus level has consistently decreased. However, it seems that recent investments at these levels are causing some bottlenecks at the access network level.

- Twenty of the GÉANT partner NRENs currently offer dedicated wavelengths (lambdas) to their customers.

- On the European level, these lambdas are complemented by the GÉANT Plus and GÉANT Lambda services.

- Around 700 wavelength circuits (lambdas) are now in use for high-bandwidth, low-jitter transport (up from 200 in 2009).

Traffic also continues to grow: total IP levels have increased eight-fold in the past seven years. In the past year, the rate of growth has again accelerated. Over the entire seven-year period, it was more than 37% per year.

- In the 33 European countries that submitted relevant data for this *Compendium*, the average traffic per inhabitant grew from 128 MB/month in 2007 to 231 MB/month in 2010, representing an average annual growth rate of 21.7%.

- Analysis confirms that there are still substantial inequalities in Europe: Bulgaria, Cyprus, Latvia, Montenegro, Serbia and Turkey all have levels of traffic per inhabitant that are substantially below the European average.

- However, in Lithuania and Romania there has been a marked growth of traffic.

In 2010, global sales of laptops once again exceeded those of desktop computers. The trend is clearly towards greater mobility, and this is reinforced by the uptake of mobile broadband, which overtook fixed broadband in 2009. A change with respect to last year is that several NRENs are now involved in Internet use via mobile phone network operators, using various technologies. Fourteen GÉANT partner NRENs are already using these technologies; several more are interested in doing so. This is complemented by the continued development of the eduroam® service, which is now available in all GÉANT partner countries and some non-European countries.

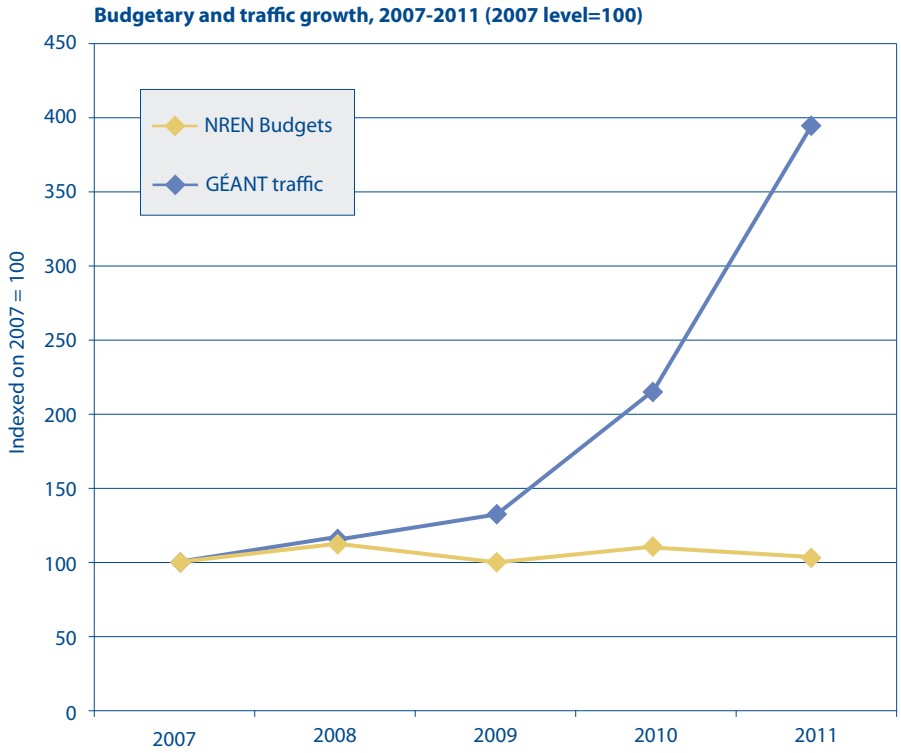
Five NRENs are already affected by the anticipated shortage of IPv4 address space; a few more see problems for their client institutions. The great majority of NRENs provide some or all of their clients with both IPv4 and IPv6 connectivity. Clients using only IPv6 remain a rare exception.

Economic and organisational challenges

In summary, NRENs now support more users, a greater usage volume and a wider range of services than ever before. All this has been achieved even though, over the past five years, overall budgets have remained virtually unchanged. Staff levels have increased slightly as a result of the advent of a new generation of networked services.

- The overall budget figures do not (yet) show that NRENs are being significantly affected by the current economic crisis, although Greece deserves special mention: following a 25% budget cut in 2010, there was a further cut of 13% in 2011. Other countries may face similar scenarios in the near future

- The overall trend is that, each year, NRENs are able to deliver greater bandwidth and more services for roughly the same amount of money as in the previous year. This reflects a general trend in the Internet sector, where the price per megabit of bandwidth continues to fall.



NRENs are coping with their budgetary difficulties in several ways, including diversifying funding sources and entering into new activities (such as brokerage, negotiating deals for clients and becoming involved in secondary schools). They may also be moving from general to more project-related funding or from long-term to short-term funding. These are just examples; there is no clear overall picture.

What does seem clear, however, is that a NREN generally constitutes an important asset for the research and educational community of the country in which it operates. In order to remain relevant, it is important that NRENs should be able to allocate resources to deploying new services for their users.

This edition of the *Compendium* shows that NRENs are aware of these challenges and are adapting to meet them. This requires a commitment from all major stakeholders, including funders and users. For NRENs, a model of governance that allows such stakeholders to participate would seem to be the most appropriate. NRENs that can operate with a certain degree of independence from their respective governments may have distinct advantages, such as easier decision-making processes and the ability to recruit and retain suitably qualified staff. This may partially explain why this model of partial independence is more common in countries where, after many years of development, research and education networking is well established.

1 BASIC INFORMATION

The TERENA *Compendium* is an authoritative reference on the development of research and education networking in Europe and beyond. Below, Section 1.1 presents information on the European NRENs that responded to the questionnaire distributed by TERENA in May 2011. Section 1.2 includes a comprehensive list of non-European NRENs and shows which of them submitted responses to the questionnaire. Section 1.3 covers the legal status of the European NRENs and their relationship with government. Section 1.4 summarises major changes in NRENs, their services and/or their users. Section 1.5 briefly examines environmental policies.

1.1 European NRENs that responded to the questionnaire

There are 54 countries in the area covered by this 2011 edition of the *Compendium* (that is, Europe and Mediterranean countries in the Middle East and North Africa). In two of those 54 countries, there is either no NREN or we have no knowledge of NREN work there. A total of 45 NRENs in the same number of countries responded to the questionnaire; many, though not all, answered all the questions. The map and Tables 1.1.1 and 1.2.2 (right) give an overview of the NRENs that submitted responses. Please note that, in most of the tables and graphs included in this edition of the *Compendium*, NRENs are identified by abbreviations of their official English names.

Table 1.1.1, which lists the European and Mediterranean NRENs, is divided into two categories: GÉANT partner countries (35 in total) and other countries. Some NRENs in the other countries have associate partner status with GÉANT; this is also shown in the table.

Table 1.1.1 - European and Mediterranean NRENs included in this *Compendium*
(TERENA members are shown in **bold**)

Country	NREN	URL
GÉANT partner countries		
Austria	**ACOnet**	www.aco.net
Belgium	**Belnet**	www.belnet.be
Bulgaria	**BREN**	www.bren.bg
Croatia	**CARNet**	www.carnet.hr
Cyprus	**CYNET**	www.cynet.ac.cy
Czech Republic	**CESNET**	www.cesnet.cz, www.ces.net
Denmark	**UNI-C**	www.forskningsnettet.dk/en
Estonia	**EENet**	www.eenet.ee
Finland	**Funet**	www.funet.fi (www.csc.fi/funet)
France	**RENATER**	www.renater.fr
Germany	**DFN**	www.dfn.de
Greece	**GRNET S.A.**	www.grnet.gr/default.asp?pid=1&la=2
Hungary	**NIIF/HUNGARNET**	www.niif.hu
Iceland	**RHnet**	www.rhnet.is
Ireland	**HEAnet**	www.heanet.ie
Israel	**IUCC**	www.iucc.ac.il
Italy	**GARR**	hwww.garr.it
Latvia	**SigmaNet**	www.sigmanet.lv
Lithuania	**LITNET**	www.litnet.lt
Luxembourg	**RESTENA**	www.restena.lu
Macedonia, FYRo	**MARNet**	dns.marnet.net.mk
Malta	**UoM/RicerkaNet**	www.um.edu.mt/itservices/about
Montenegro	**MREN**	www.mren.ac.me
Netherlands	**SURFnet**	www.surfnet.nl
Norway	**UNINETT**	www.uninett.no
Poland	**PIONIER**	www.pionier.net.pl
Portugal	**FCCN**	www.fccn.pt
Romania	**RoEduNet**	www.roedu.net


NREN
Responses received
No responses received
NREN planned but not operational
No NREN or no known NREN work
SERVICE (Red = planned)
Identity federation
VoIP service
Multimedia repository
Cloud services
Iceland
Sweden
Finland
Norway
Estonia
Latvia
Denmark
Lithuania
Russian Federation
Belarus
Ireland
United Kingdom
Netherlands
Poland
Germany
Belgium
Ukraine
Luxembourg
Czech Republic
Slovakia
Austria
Moldova
Hungary
Switzerland
France
Slovenia
Croatia
Romania
Italy
Bosnia/
Herzegovina
Serbia
Bulgaria
Montenegro
Macedonia
Georgia
Albania
Armenia
Azerbaijan
Spain
Portugal
Turkey
Greece
Syria
Malta
Tunisia
Cyprus
Algeria
Morocco
Israel
Jordan
Egypt

Table 1.1.1 - continued

Country	NREN	URL
GÉANT partner countries		
Slovakia	**SANET**	www.sanet.sk
Slovenia	**ARNES**	www.arnes.si
Spain	**RedIRIS**	www.rediris.es & www.red.es
Sweden	**SUNET**	www.sunet.se
Switzerland	**SWITCH**	www.switch.ch
Turkey	**ULAKBIM**	www.ulakbim.gov.tr
United Kingdom	**JANET(UK)**	www.ja.net
Other European and Mediterranean countries		
Albania		
Algeria	CERIST	www.arn.dz
Armenia	ASNET-AM	www.asnet.am
Azerbaijan	**AzScienceNet**	www.science.az
Azerbaijan	AZRENA	www.azrena.org
Belarus	**BASNET**[1]	www.basnet.by
Bosnia/Herzegovina	SARNET[2]	
Egypt	EUN	www.eun.eg
Georgia	GRENA	www.grena.ge
Jordan	JUNet	www.junet.edu.jo
Lebanon		
Libya		
Moldova	**RENAM**[1]	www.renam.md
Morocco	MARWAN	www.marwan.ma
Palestinian Territories		
Russian Federation	e-ARENA[1]	www.e-arena.ru
Serbia	**AMRES**	www.amres.ac.rs/index.php?lang=ser
Syria	HIAST	
Tunesia	RNU	www.cck.rnu.tn
Ukraine	UARNet	www.uar.net/en
Ukraine	URAN[1]	www.uran.ua

[1] These NRENs have associate partner status in the GÉANT project (Belarus, Moldova, Russian Federation, Ukraine).
[2] SARNET is active only in the Republika Srpska entity of Bosnia/Herzegovina.

Legend for Tables 1.1.1, 1.1.2 and 1.2.2

	Responses received
	No responses received
	NREN planned but not operational
	No NREN or no known NREN work in this country

1.2 NRENs in other regions and continents

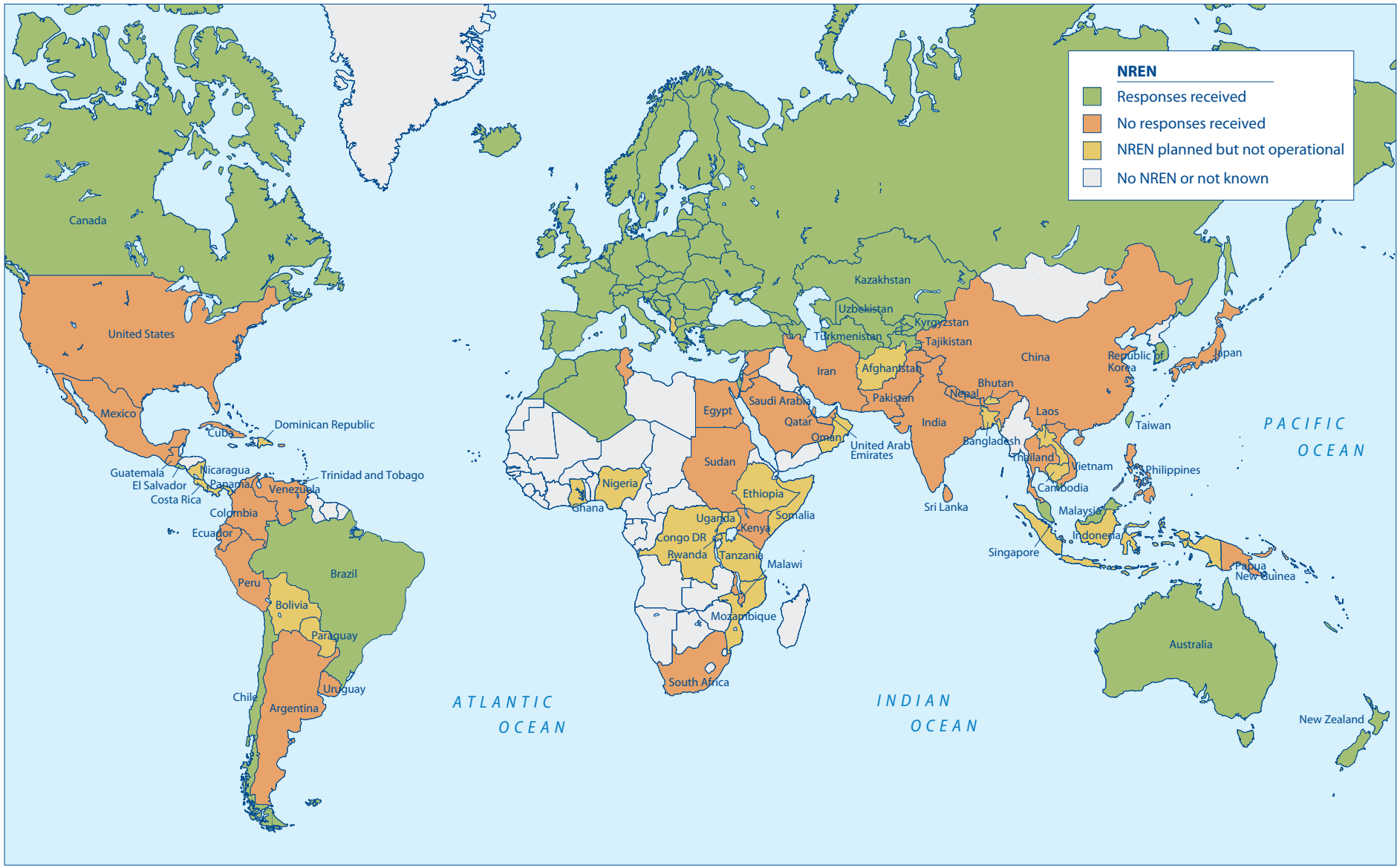
Table 1.2.1 (below) lists sources of information on NRENs in other continents.

Tables 1.2.1 - Information on non-European NRENs

Area	Organisation/project	URL
Eastern and Southern Africa	Ubuntunet Alliance	www.ubuntunet.net
Latin America	CLARA	www.redclara.net
Asia/ Pacific	APAN	www.apan.net
Central Asia	CAREN	caren.dante.net/server/show/nav.2290
Canada	CANARIE	www.canarie.ca
USA	Internet2	www.internet2.edu
	National Lambdarail	www.nlr.net
	National Regional Networks consortium	www.thequilt.net

Several projects aim to connect research communities around the globe to the GÉANT network. These are listed at **www.geant.net/Network/GlobalConnectivity**.

Table 1.2.2 lists those NRENs and NREN initiatives in other parts of the world of which we are currently aware. Note that this list is not complete: there may be other NRENs of which we have no knowledge. Also, in some countries the situation may be subject to rapid change. Thirteen NRENs from non-European


NREN
Responses received
No responses received
NREN planned but not operational
No NREN or not known
Canada
United States
Mexico
Cuba
Dominican Republic
Guatemala
El Salvador
Costa Rica
Nicaragua
Panama
Venezuela
Trinidad and Tobago
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Chile
Argentina
Uruguay
ATLANTIC OCEAN
Kazakhstan
Uzbekistan
Kyrgyzstan
Turkmenistan
Tajikistan
China
Republic of Korea
Japan
Iran
Afghanistan
Pakistan
Bhutan
Nepal
India
Bangladesh
Laos
Thailand
Vietnam
Cambodia
Philippines
Taiwan
Malaysia
Indonesia
Singapore
Sri Lanka
Egypt
Saudi Arabia
Qatar
Oman
United Arab Emirates
Sudan
Nigeria
Ghana
Ethiopia
Somalia
Uganda
Kenya
Congo DR
Rwanda
Tanzania
Malawi
Mozambique
South Africa
INDIAN OCEAN
PACIFIC OCEAN
Australia
Papua New Guinea
New Zealand

countries submitted data for this *Compendium*; they are highlighted in green. Their full responses are available at **www.terena.org/activities/compendium**.

Further information on Latin American NRENs is published in the CLARA Compendium of Latin American National Research and Education Networks (2010), available at **www.redclara.net/index.php?option=com_content&view=article&id=142&Itemid=402&lang=en**

Table 1.2.2 - NRENs known to be operating in other countries

Country	NREN	URL
Afghanistan	AfREN	
Argentina	INNOVA|RED	www.innova-red.net
Australia	AARNet	www.aarnet.edu.au
Bangladesh	BdREN	www.bdren.net.bd
Bhutan	DrukREN	
Bolivia	BOLNET	www.adsib.gob.bo
Brazil	RNP	www.rnp.br
Cambodia	CamREN	
Canada	CANARIE	www.canarie.ca
Chile	REUNA	www.reuna.cl
China	CERNET	www.edu.cn
China	CSTNet	www.cstnet.net.cn
China (Hong Kong)	HARNET	www.harnet.hk
Colombia	RENATA	www.renata.edu.co
Congo DR	eb@le	www.ebale.cd
Costa Rica	RedCONARE	
Cuba	RedUNIV	www.mes.edu.cu
Dominican Republic	RADEI	
Ecuador	CEDIA	www.cedia.org.ec
Egypt	EUN	www.eun.eg
El Salvador	RAICES	www.raices.org.sv
Ethiopia	EthERNet	

Table 1.2.2 - continued

Country	NREN	URL
Ghana	GARNET	www.garnet.edu.gh
Guatemala	RAGIE	www.ragie.org.gt
India	ERNET	www.eis.ernet.in
Indonesia	INHERENT-DIKTI	www.inherent-dikti.net
Iran	IRANET/IPM	www.iranet.ir
Japan	SINET	www.sinet.ad.jp
Japan	JGN2plus	www.jgn.nict.go.jp/english
Kazakhstan	KazRENA	www.kazrena.kz
Kenya	KENET	www.kenet.or.ke
Korea, Republic Of	KOREN	www.koren.kr
Korea, Republic Of	KREONET	www.kreonet.re.kr/en
Kyrgyzstan	KRENA-AKNET	www.krena.kg
Laos	LERNET	
Malawi	MAREN	www.malico.mw/maren
Malaysia	MYREN	www.myren.net.my
Mexico	CUDI	www.cudi.edu.mx
Mozambique	MoRENet	morenet.mct.gov.mz
Nepal	NREN	www.nren.net.np
New Zealand	REANNZ	hwww.karen.net.nz
Nicaragua	RENIA	hwww.renia.net.ni
Nigeria	ngNREN	
Oman	OMREN	www.trc.gov.om
Pakistan	PERN	www.pern.edu.pk
Panama	RedCyT	
Papua New Guinea	PNGARNet	www.pngarnet.ac.pg
Paraguay	Arandu	
Peru	RAAP	www.raap.org.pe
Philippines	PREGINET	www.pregi.net
Qatar	Qatar Foundation	www.qf.org.qa
Rwanda	RwEdNet	

Table 1.2.2 - continued

Country	NREN	URL
Saudi Arabia	ISU	www.kacst.edu.sa/en/depts/isu/Pages/Home.aspx
Singapore	SingAREN	www.singaren.net.sg
Somalia	Somaliren	www.somaliren.org
South Africa	SANReN	www.sanren.ac.za
South Africa	TENET	www.tenet.ac.za
Sri Lanka	LEARN	www.learn.ac.lk
Sudan	SUIN	www.suin.edu.sd
Taiwan	TWAREN	www.nchc.org.tw/en
Tajikistan	TARENA	www.tarena.tj
Tanzania	TERNET	www.ternet.or.tz
Thailand	ThaiREN	www.thairen.net.th
Thailand	UniNet	www.uni.net.th/UniNet/Eng/index_eng.php
Trinidad and Tobago	NKLN	
Turkmenistan	TuRENA	www.science.gov.tm/en/turena
Uganda	RENU	www.renu.ac.ug
United Arab Emirates	ANKABUT	www.kustar.ac.ae/ankabut
United States	Internet2	www.internet2.edu
Uruguay	RAU	www.rau.edu.uy
Uzbekistan	UzSciNet	www.uzsci.net
Venezuela	REACCIUN	www.reacciun2.edu.ve
Vietnam	VinaREN	www.vinaren.vn

1.3 Legal form of NRENs

NRENs have various legal forms. NREN names and their translations may be misleading: what is called a 'foundation' in one country may be quite different from a 'foundation' in another country. The same is true of several other designations, including 'association'. This section distinguishes two parameters which, together, help to characterise the legal form of a NREN:

1) Its relationship with government; and
2) Whether it is a separate legal entity.

Relationship with government

In this *Compendium*, we distinguish three situations:

a) Some NRENs are under the direct control of government. This is the case if a NREN is (part of) a government agency or is a parastatal.
b) Some NRENs operate independently of government to a certain extent; for example, those that are separate legal entities with governing boards at least half of whose members are government appointed. Also, some NRENs that are government agencies enjoy a certain degree of autonomy comparable to that of NRENs that are separate legal entities.
c) Some NRENs have no direct government ties, even though, typically, the majority of their client institutions are government-funded.

Separate legal entity

Many NRENs operate as separate legal entities.

A combination of the two parameters leads to six categories, as shown in Map 1.3.1 (right).

It seems self-evident that for an NREN to develop, the commitment of all its major stakeholders – including funders and users – is required. A governing model that allows all such stakeholders to participate would seem to be the most appropriate; such a situation can be achieved in various ways.

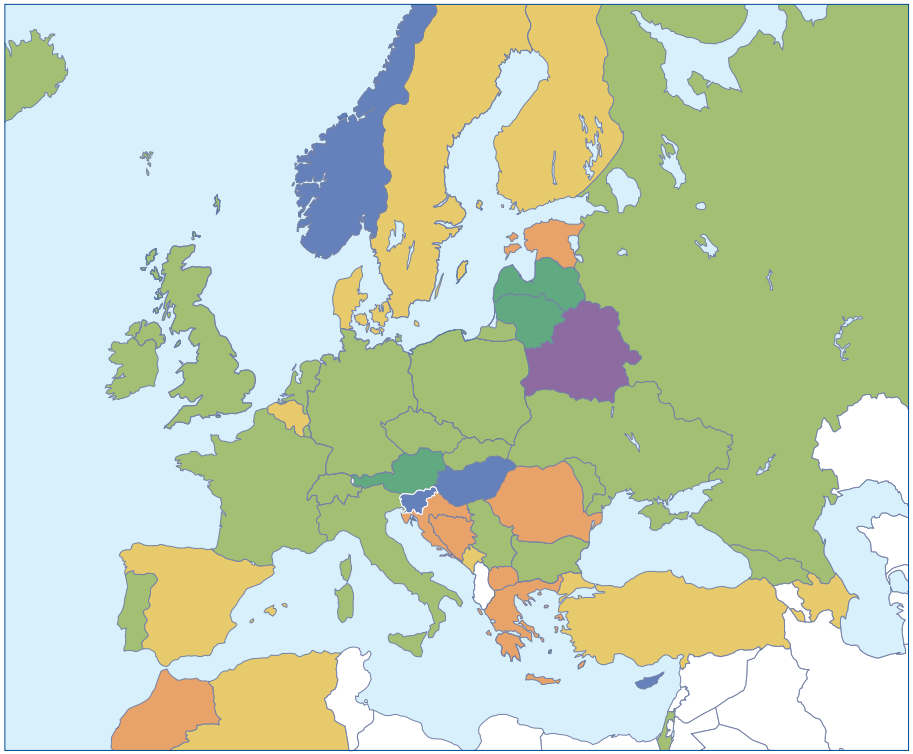
NRENs that can operate with a certain degree of independence from their respective governments may have distinct advantages, such as easier decision-making processes and the ability to recruit and retain suitably qualified staff, partly by setting salaries at competitive levels. This may partially explain why this

model is more common in countries where, after many years of development, research and education networking is well-established.

Legend for Table 1.3.1

	NRENs with no direct government control, separate legal entities
	NRENs with no direct government control, not separate legal entities
	NRENs which are largely government-controlled, separate legal entities
	NRENs which are largely government-controlled, not separate legal entities
	NRENs which are entirely government-controlled, separate legal entities
	NRENs which are entirely government-controlled, not separate legal entities

Map 1.3.1 - Legal form of NRENs



1.4 Major changes in NRENs

All the NRENs covered by this 2011 edition of the *Compendium* were requested to briefly describe any major changes in their mandate or remit, user-base, or technology and services that occurred in the past year or were expected to occur in the coming year. For the full responses, see Appendix I.

The descriptions received by TERENA show that the changeover to dark fibre infrastructures, capacity and configuration is continuing. Core capacities in many countries are now at 10 Gb/s or above. 100 Gb/s on parts of the backbone is no longer the exclusive domain of a few advanced NRENs - Romania, for example, is now able to deploy a 100 Gb/s lambda. In many countries, this trend is accompanied with an expansion and upgrading of connectivity to client institutions; in increasing numbers of countries, clients are served with dark-fibre connections. In an ever widening range of countries, large users are now being connected at 10 Gb/s capacities.

Several NRENs mention that they are ready for the transition to IPv6. For further information on this topic, see Section 4.6.

In the area of services, the situation is more mixed. Some NRENs (including Forskningsnettet of Denmark) have decided to concentrate on connectivity services and to leave other services to others. JANET(UK) remarks: *"We've made and will continue to make organisational changes to ensure that we are best able to deliver the required services in the developing financial situation."* Other NRENs are working hard to expand their range of services. Thus, in Ireland *"The role of the Client Services Management has been introduced as a fundamental part of HEAnet operations"*. In Greece, a full set of data services will be deployed and a data centre established. Several NRENs mention setting up or expanding Voice over IP, videoconferencing and other services.

Several NRENs reported that they were affected by institutional changes; for example, a change in Finland's university system, the establishment of a separate top-level domain registration service in Estonia or the adoption of new regulations in Macedonia.

1.5 Environmental policies

Environmental issues started to feature on NREN agendas a few years ago. NRENs and their users began to realise that it is important for NRENs to address such issues, to measure and reduce energy consumption, and to promote green uses of network technology in order to reduce greenhouse gas (GHG) emissions. Progress on environmental issues has been made in various NRENs.

Since last year, however, progress has been relatively slow, perhaps due to the economic crisis. Compared to last year, one more NREN (FCCN) has indicated that it has an environmental policy. Two NRENs have environmental information on their websites.

As part of the GN3 project, four NRENs (HEAnet, PSNC, NIIF/HUNGARNET and SURFnet) and one regional network (NorduNET) have audited their GHG emissions. Three more NRENs are planning such an audit. For further information, see **www.geant.net/Network/Environmental_Impact/Pages/home.aspx**

Table 1.5.1 - NREN environmental policies in place

Country	NREN	Policy	URL
Estonia	EENet	yes	
Hungary	NIIF/HUNGARNET	yes	
Ireland	HEAnet	yes	www.heanet.ie/about/environmental_policy
Portugal	FCCN	yes	
UK	JANET(UK)	yes	www.ja.net/documents/company/environmental-policy.pdf

2 USERS/CLIENTS

Section 2.2 (below) indicates how many users in the various categories are actually connected to the NREN (i.e. the 'market shares'). Section 2.3 examines the typical bandwidths. A new section, 2.4, looks at shared connections and at non-routed connectivity. Section 2.5 highlights several other technologies that NRENs deploy in their access networks or make available to end-users.

2.1 Overview

As shown in previous editions of the *Compendium*, all the NRENs covered by this publication are allowed to connect universities and research institutes. Nearly all may connect institutes of further education, as well as libraries and museums. Such information is not repeated in this year's edition: even though NRENs differ greatly in this respect, there have been no significant changes in the past year.

Even though an NREN may connect a certain institution, this does not necessarily mean that it actually does. In the university sector, NRENs obviously have very high market shares; in other areas, the situation differs greatly from country to country.

For universities within the GÉANT area, the typical connection capacity is now gigabit or greater — a tremendous increase compared with the situation a few years ago. Capacities exceeding 10 Gb/s are currently being introduced. All other categories of users have significantly lower capacities. In the European and Mediterranean countries that are not part of the GÉANT project, gigabit connections are not yet prevalent.

Fifteen of the GÉANT partner NRENs currently offer some form of non-routed connectivity. In certain cases, this is done only for specific projects. SURFnet offers optical private networks (OPN) to many institutions. In the other countries, non-routed connectivity is only provided by the more advanced NRENs.

Connection sharing is prevalent, although in most cases this is done for reasons of cost effectiveness, particularly for smaller institutions or for institutions sharing the same premises.

Like last year, TERENA asked NRENs about the technologies that they are deploying in their access networks or are making available to individual end-users. A change compared to last year is that several NRENs are now involved in Internet use via mobile phone network operators, using various technologies. Fourteen GÉANT partner NRENs are using licensed or unlicensed spectrum (that is, wireless networking that uses part of the radio spectrum); several others are interested in this technology.

2.2 Approximate market shares

Table 2.2.1 provides an overview of the number of institutions in each user category, as well as an indication of the percentage of users that are serviced by each NREN. Only approximate percentages were obtained from *Compendium* respondents.

Many NRENs operating in a strong hierarchy of Metropolitan or Regional Area Networks (MAN/RAN) were unable to provide connection figures but did indicate that they service high percentages of their respective communities. For additional information on individual NRENs, see the *Compendium* website: **www.terena.org/compendium**

Legend for Table 2.2.1

	All or nearly all institutions are connected
	More than half of the institutions are connected
	About half of the institutions are connected
	Less than half of the institutions are connected
	None or very few of the institutions are connected
	Unknown/not applicable/not answered

Table 2.2.1 – Approximate market shares, number of connected institutions

Country	Universities	Institutes of further education	Research institutes	Secondary schools	Primary schools	Libraries, museums, archives, cultural institutions	Hospitals (other than university hospitals)	Government departments (national, regional, local)
GÉANT partner countries								
Austria	36	1	29			11	4	35
Belgium	68	4	42	5		11	13	48
Bulgaria	22	2	50	1,500	500	15	5	
Croatia	106	41	36	422	905	10	15	11
Cyprus	8	1	3					
Czech Republic	26	11	23	115	19	51	41	37
Denmark	8	7	12	0	0	5	2	4
Estonia	27	11	19	52	35	84	0	30
Finland	50		12			5		8
France	429	331	371			12	10	29
Germany								
Greece	44	144	26	4,206	9,855	8		753
Hungary	26	31	73	34	0	210	52	8
Iceland	9	2	11	1		1		
Ireland	25	5	10	800	3,200	0	0	8
Israel	12	0	5	0	0	0	0	0
Italy	145	0	157	10	1	26	49	3
Latvia	14	6	14	3		3		
Lithuania	43	80	31	577	52	43	9	35

Table 2.2.1 – continued

Country	Universities	Institutes of further education	Research institutes	Secondary schools	Primary schools	Libraries, museums, archives, cultural institutions	Hospitals (other than university hospitals)	Government departments (national, regional, local)
GÉANT partner countries								
Luxembourg	5	2	19	59	145	12	1	3
Macedonia, FYRo	19	0	5	0	0	50	0	1
Malta	1	2	3					
Montenegro	19	1	2			2		1
Netherlands	14	64	32	0	0	19	12	0
Norway	8	56	79	6	4	14	0	0
Poland	168	17	199	110	13	136	35	105
Portugal	42		12	0	0	3	0	14
Romania	50	10	55	360	140	40		30
Slovakia	38	7	20	250	100	6		
Slovenia	4	20	54	153	532	194	0	12
Spain	103	0	166	0	0	25	54	76
Sweden	30	9	4			19		20
Switzerland	43	3	10	2				6
Turkey	812		14			3		9
United Kingdom	190	600	40			9		10
Other countries								
Algeria	54	33	25					5
Azerbaijan			30			4		
Belarus	10		57			17	5	9
Bosnia/Herzegovina	25	1	1					
Georgia	9	10	35	3		8	2	7
Moldova	9	2	36	2		14	5	5
Morocco	14	77	8	0	0	2	0	2
Russian Federation	250		240					
Serbia	84	6	36	8		19	3	2
Australia	41	13	24	225	223	9		1

Table 2.2.1 – continued

Country	Universities	Institutes of further education	Research institutes	Secondary schools	Primary schools	Libraries, museums, archives, cultural institutions	Hospitals (other than university hospitals)	Government departments (national, regional, local)
Other countries								
Brazil	406	0	115	1	1	11	14	32
Canada	89	184	70	1,300	700	26	62	50
El Salvador	5			0	0			0
Kazakhstan	51		7	5			1	2
Korea	52	0	55	1	0	5	1	17
Kyrgyzstan	19	17	3	17	0	3	2	1
Malaysia	68							
New Zealand	8	13	13	31	43	5	0	2
Taiwan	120	20	20	500	1,000	5	5	20
Tajikistan	12		8	72		10	4	5
Turkmenistan	17		14	26		1	4	2

Legend for Table 2.2.1

	All or nearly all institutions are connected
	More than half of the institutions are connected
	About half of the institutions are connected
	Less than half of the institutions are connected
	None or very few of the institutions are connected
	Unknown/not applicable/not answered

2.3 Typical bandwidths

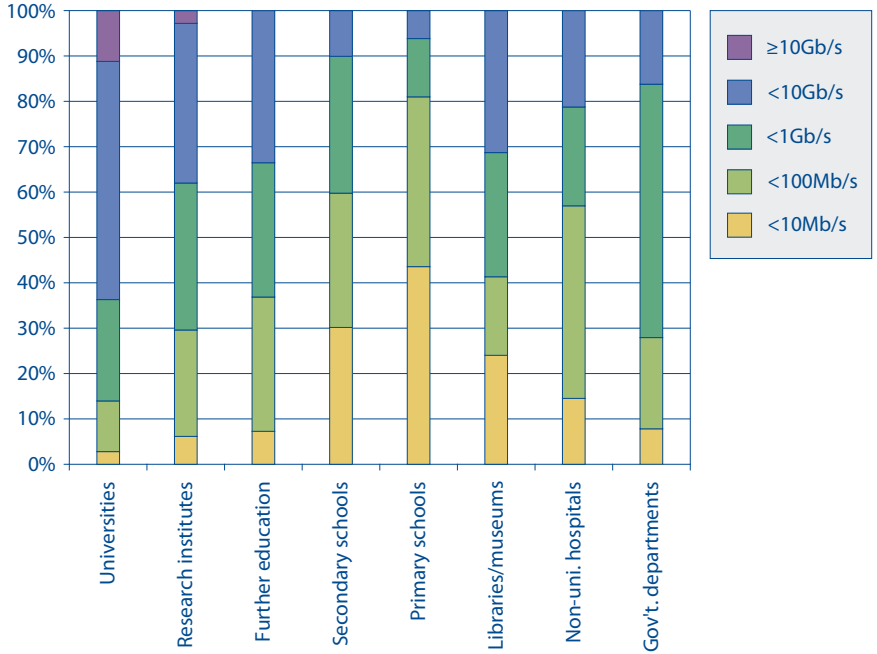
From the 2008 edition of the *Compendium*:

> *In 2003, the 'average' university was connected at Megabit capacity; by 2008, that had changed to Gigabit capacity.*

The typical capacity for universities within GÉANT partner countries is now gigabit or greater, while 10 Gb/s is becoming increasingly common. All other user categories have much lower connection speeds.

Graph 2.3.1 (below) gives an overview of the distribution of typical bandwidths available to NREN users. Note that not all NRENs provided information relevant to this overview, so the set of countries is not exactly the same in each user category.

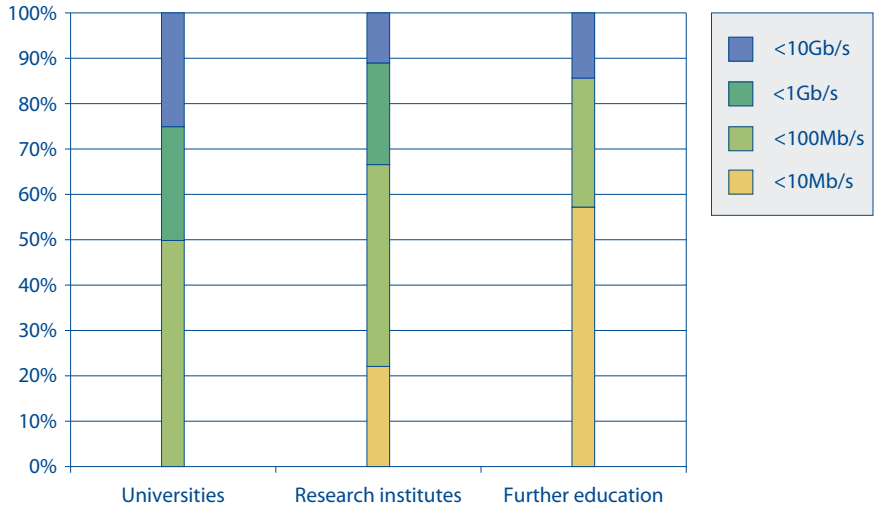
Graph 2.3.1- Typical bandwidth, GÉANT partner countries



We have also examined the spread within individual countries. It should be noted that there are large differences in this regard. In some countries, all or most institutions in a particular category are connected at similar capacities. In other countries, there can be large capacity differences at the national level.

In countries outside the GÉANT area, the situation is quite different: gigabit connections are being introduced but are not yet prevalent. Graph 2.3.2 (below) presents a more limited set of user categories than those shown in Graph 2.3.1 (left), because fewer countries provided the necessary information.

Graph 2.3.2- Typical bandwidth, other countries



2.4 Shared connections, non-routed connectivity

Institutions connected by NRENs are invariably connected using the Internet Protocol for their primary network access. However, with the emergence of network technologies and growing dark fibre infrastructures, other underlying technologies are used to serve special applications.

Thus, institutions may be given the opportunity to set up their own virtual private networks (VPNs) based on a fibre infrastructure provided by the NREN. This may be useful for universities with several campuses in widely spread locations, for example. Such universities may (and in almost all cases will) use the Internet Protocol on their VPNs — but they provide this themselves and it is no longer under the control of, or even visible to, the NREN.

For this edition of the *Compendium*, TERENA asked NRENs whether any of their institutions are serviced specifically by connectivity where IP is not explicitly provided. We also asked the NRENS whether they allow their institutions to share a connection if they wish to.

The responses show that 15 of the GÉANT partner NRENs currently provide some form of connectivity where IP is not explicitly offered. In some cases, this is done only for specific projects. SURFnet of the Netherlands offers optical private networks (OPN) to a large number of institutions.

In the non-GÉANT countries, this type of connectivity is only provided by the more advanced NRENs, such as CANARIE of Canada and KREONET of Korea.

For smaller institutions or for institutions sharing the same premises, connection sharing is more prevalent, although in most cases this is done for reasons of cost effectiveness.

Table 2.4.1 - Non-routed connectivity and connection sharing

Country	Non-IP connectivity?	Details	Connection sharing?	Details
GÉANT partner countries				
Austria	yes	plain Layer 2 VLAN infrastructure	yes	Institutions can use one connection with different VLANS configured to connect to ACOnet.
Belgium	yes	We currently offer 2 types of non-IP connectivity: Point-to-Point Ethernet & Multipoint Ethernet.	yes	Some organisations share the bandwidth with other smaller organisations in the neighbourhood for various reasons (pricing, maximisation of bandwidth usage,...) Belnet contracts with only one party.
Croatia	no		yes	If we have two or more institutions on the same address, we provide them one link with separate IP ranges for each of them.
Czech Republic	yes	EoMPLS tunnels between some institution departments (L2 connectivity)	no	
Denmark	no		no	
Estonia	no		yes	Cost efficiency and optimal cabling are primary targets.
Finland	no		yes	Small remote sites may use connections of local institutions.
France	yes		yes	Happens occasionally and on a case-to-case basis.
Germany	yes	Especially HPC and GRID projects.	yes	Several institutions share an IP access link to the X-WIN-router.
Greece	yes	In addition to the IP network topology, L2 VPNs are established among many GRNET clients.	yes	GRNET has presence within the largest institutions. In several cases, smaller institutions connect to these institutions and share their uplink.

Table 2.4.1 - continued

Country	Non-IP connectivity?	Details	Connection sharing?	Details
GÉANT partner countries				
Hungary	yes	DWDM access is also provided in some cases.	yes	In a few cases separate smaller R&E organisations access the network through a major university.
Ireland	yes	Some client institutions have subsidiary entities or affiliates which HEAnet connects at layer 2.	yes	By mutual agreement and where the access policy and operational service is managed by a single client.
Israel	no		no	
Italy	no		yes	
Latvia	no		yes	If they are in one building, they can share costs of the connectivity.
Lithuania	no		yes	According to the LITNET AUP.
Luxembourg	yes	VLANs and Lambdas.	yes	If 2 or more institutions are in the same building, they share the same connection.
Macedonia, FYRo	no		yes	If they share the premises (building) and are both eligible to be connected.
Montenegro	no		yes	In a few cases where it is too expensive and not profitable to establish additional fibre optics, institutions share existing, and interconnect via, copper UTP.
Netherlands	yes	About 90 locations are connected by means of an OPN (a set of lightpaths) to the main location of their institution.	no	
Norway	no		yes	Some institutions share premises.
Poland	yes	For projects	yes	

Table 2.4.1 - continued

Country	Non-IP connectivity?	Details	Connection sharing?	Details
GÉANT partner countries				
Portugal	yes	RCTS Plus and RCTS Lambda connectivity services are provided to users. Similar to the GÉANT Plus and GÉANT Lambda connectivity Services.	yes	Connection sharing must be individually approved and must operate on a strict not-for-profit basis.
Romania	no		no	
Slovakia	no		yes	
Slovenia	yes	For connecting two locations of the same institution Arnes is offering VPN connectivity and PtP L2 connectivity.	no	
Spain	yes	112 well-known centres that participate in the Spanish Emergency Network, which is supported by RedIRIS providing a L2-VPN to all sites.	yes	There is no specific rule. If two institutions reach an agreement to share the connection, this is accepted by us. Each institution has its own address range. For the management of that physical connection, we require a contact technical point. For all the other services we provide, we require technical contact points for each institution.
Sweden	no		yes	In rare circumstances, especially in rural areas.
Switzerland	yes	6 sites with OPN-only connectivity.	yes	Universities may connect other – typically smaller – schools behind them and provide them transit to SWITCH.
Other countries				
Algeria	no		no	
Azerbaijan	no		no	
Belarus			no	

Table 2.4.1- continued

Country	Non-IP connectivity?	Details	Connection sharing?	Details
Other countries				
Bosnia/ Herzegovina	no		no	
Georgia	no		no	
Morocco	no		yes	A university can connect all the institutions belonging to it.
Serbia	no		no	
Australia	no		no	
Brazil	no		yes	Four institutions located in rural regions, where the costs of telecommunication are high, are allowed to share a connection.
Canada	yes	Dedicated lightpaths between institutions.	yes	Enabling VLAN tagging to allow sharing of a connection.
El Salvador	no		no	
Kazakhstan	yes	Metro VPN, regional VPN.	yes	Connection between departments and buildings.
Korea	yes	• L2 VPN based on Carrier Ethernet for Korea E-VLBI, etc. • L1 VPN (Lightpath) for connecting several hospitals, supercomputers, etc.	yes	
Kyrgyzstan	no		no	
Malaysia			yes	Yes, if they are close by, normally a teaching hospital located in the university area.
New Zealand	no		no	
Taiwan	yes	Some institutions, including TANET, uses TWAREN's VPLS VPN or Lightpath services to serve their internal communication needs.	no	
Tajikistan	no		no	
Turkmenistan	no		no	

2.5 Other technologies used by NRENs[1]

As in the previous year's questionnaire, we asked NRENs about the technologies they are deploying in their access networks or are making available to individual end-users. The responses are shown in Table 2.5.1 (right). Note that not all NREN respondents answered these questions. Note also that the questionnaire did not cover the extent to which these technologies are currently being deployed — the only question was whether they are being deployed at all. Questions were asked about seven specific technologies:

- Fibre to the Home / Fibre to the Office (FTTH/FTTO); i.e. making optical fibre technology available to the home or office end-user. Seven GÉANT partner NRENs report that they are doing this at the access network level; in one NREN this is at the trial stage and one more is planning to do so in the near future. Several of the non-GÉANT NRENs are also deploying these technologies.
- DSL: connecting users via (A)DSL: this technology is quite common at the access network level.
- Wireless LAN: the situation is similar to that of DSL, although the set of countries is not the same.
- Internet use via mobile phone network operators: several NRENs are now involved in this, using various technologies — a marked increase compared to last year.
- Several NRENs are already using, or are interested in, satellite technology.
- Fourteen GÉANT partner NRENs are using licensed or unlicensed spectrum (that is, wireless networking that uses part of the radio spectrum); several more are interested in this technology.

The list is not comprehensive – several NRENs use other technologies as well.

Generally, NRENS do not provide mobile access to licensed spectrum. Mobility access to WiFi by using eduroam® is enabled by all GÉANT members and many other NRENs.

[1] With contributions from Mike Norris, HEAnet.

Connectivity for mobile users is usually provided by conventional ISPs and mobile network operators. Nevertheless, NRENs may be able to provide important services to mobile student and staff populations. Middleware and security services are essential, and NRENs are best placed to deliver these to the education and research communities (for further information, see Sections 5.2 and 5.3).

Table 2.5.1 – Technologies deployed at the access level network

Country	FttH/FttO	DSL	WLAN	3G – via MNOs (Mobile Network Operators)	3G – via VMNOs (Virtual Mobile Network Operators)	3G – via APNs (Access Point Names)	Satellite	Other licensed spectrum	WiFi off-campus– using eduroam®	WiFi off-campus– using MNOs	Other unlicensed spectrum
GÉANT partner countries											
Austria	no	no	no	no	no	no	no	no	no	no	no
Belgium	no	no	no	no	no	no	no	no	no	no	no
Cyprus			plan								
Czech Republic	no	yes	yes	no	no	no	no	no	no	no	no
Denmark	no	no	yes	no	no	no	no	no	no	yes	no
Estonia	no	no	no	no	no	no	no	no	yes	no	no
Finland	yes		yes	plan							
France	plan	plan	no				yes		yes		
Greece		yes	yes						yes		
Hungary	trial	yes		yes		yes		yes	yes		
Iceland	no	no	no	no	no	no	no	no	no	no	no
Ireland	yes	yes	no	no	plan	trial	yes	yes	plan	yes	yes
Israel		yes									
Latvia		yes	yes						yes		
Lithuania	yes	no	yes	no	no	no	no	yes	yes	no	yes
Luxembourg	yes	yes	yes						yes		
Macedonia, FYRo	no	no	plan	no	no	no	no	no	yes	no	no
Malta			yes								
Netherlands	no	no	trial	trial	no	trial	no	no	trial	plan	no
Norway	no	no	no	no	no	no	no	no	plan	no	trial
Poland	yes	no	yes	no	no	no	no	no	yes	no	no
Portugal	no	yes	no	no	no	no	no	no	no	no	no

Table 2.5.1 – continued

Country	FttH/FttO	DSL	WLAN	3G – via MNOs (Mobile Network Operators)	3G – via VMNOs (Virtual Mobile Network Operators)	3G – via APNs (Access Point Names)	Satellite	Other licensed spectrum	WiFi off-campus– using eduroam®	WiFi off-campus– using MNOs	Other unlicensed spectrum
GÉANT partner countries											
Romania	yes	no	yes	no	no	no	no	no	yes	no	no
Slovakia	yes	no	yes	no	no	no	no	yes	yes	no	yes
Slovenia	yes	yes	yes	no	no	no	no	no	no	no	trial
Spain									yes		
Sweden	no	no	no	no	no	no	no	no	trial	no	no
Switzerland											trial
United Kingdom	no	no	no	plan	no	no	no	no	plan	no	no
Other countries											
Algeria	yes	yes									
Azerbaijan		yes	yes						plan		
Belarus		yes									
Bosnia/Herzegovina	yes	no	no	no	no	no	no	no	no	no	no
Georgia		yes	yes								
Moldova	yes	yes	yes						plan		
Russian Federation	yes	yes	yes				yes				
Serbia		yes	no	plan	no	plan	no	no	yes	no	no
Ukraine	yes										
Australia	trial	no	no	plan	no	no	no	yes	plan	no	no
Brazil	yes						yes				
Canada							yes				
Kazakhstan	yes	yes	yes								
Kyrgyzstan	yes		plan								
Malaysia	yes	yes									
New Zealand	no	no	no	no	no	no	no	yes	no	no	no
Taiwan	no	no	no	no	no	no	no	no	no	no	no
Tajikistan	yes	yes	yes								
Uzbekistan	no	yes	yes	no	no	no	no	plan	no	no	

3 NETWORK AND CONNECTIVITY SERVICES

This section provides insights into several important network characteristics. Section 3.2 presents information on Network Operations Centres. Section 3.3 examines PoPs (points of presence), optical PoPs and numbers of managed circuits. Section 3.4 provides information on the core capacity of networks. Section 3.5 highlights the external links of NRENs. Section 3.6 documents recent developments in dark fibre. Section 3.7 focuses on cross-border dark fibre links. Section 3.8 on Bandwidth on Demand is included in the *Compendium* for the first time this year. Section 3.9 includes an overview of major expected network developments.

3.1 Overview

Although NRENs differ in many respects, including network architecture, they all have a Network Operations Centre (NOC). NOCs are vital elements in the delivery of connectivity services to NREN users. In the GÉANT partner countries, most NRENs directly employ NOC staff or use a combination of in-house and outsourced staff. That NOC staff size varies considerably – from 1 FTE in Cyprus to 53 in the UK – is due not only to network size but also to differences in the NOC functions.

The number of PoPs on a network is one indicator of the amount of resources that the NREN needs in order to maintain that network. Section 3.3 on PoPs and routing shows that, in this respect, there are major differences between NRENs. Many NRENs now provide optical PoPs in various locations.

There are also major differences in the number of managed circuits. These differences are related both to the categories of connected users and to the way in which they are connected.

In most GÉANT partner countries, the typical core capacity is now 10 Gb/s. This is also the median capacity, up from 2 Gb/s in 2007. This capacity is no longer a hard limit: many NRENs have access to dark fibre (see Section 3.6 below), which is potentially able to handle high capacities, so they can increase capacity easily and economically whenever required.

In the other countries, the trend that was evident last year continues: they have profited from introducing affordable Gigabit Ethernet technology. Network capacity is not growing linearly, but step-wise. Comparing the growth in core capacity with the growth in overall traffic – documented in Section 4.3 (below) – reveals that, roughly speaking, these two trends keep pace with each other. In addition, many NRENs now offer several point-to-point circuits and lightpaths, which provide additional capacity that is not usually included in normal traffic statistics.

In general, connections not only to the European academic backbone network (i.e. GÉANT) but also to the general Internet are of crucial importance to NRENs. Currently, average connections via cross-border fibre and to the commercial Internet jointly account for over 50% of the total external connectivity. The next largest categories are connections to Internet exchanges and connections to GÉANT and NORDUnet, which together account for 38%. Total capacity has grown since the previous year, but not equally in all connection categories. The areas of greatest expansion have been cross-border fibre and connections to commercial Internet providers. However, there are major differences between NRENs. There is also considerable fluctuation from year to year, because this area is highly dynamic.

The maps in Section 3.6 illustrate the rapid developments in dark fibre that have occurred in recent years. Many NRENs, though not all, predict a further increase, by 2012, in the percentage of their network accounted for by dark fibre.

Another continuing development is the implementation of cross-border dark fibre links between NRENs. Section 3.7 presents information on current and planned links of this type, in both map and table format.

Of the GÉANT partner NRENs, 26% currently offer a Bandwidth on Demand service or are planning to do so. A further 17% indicate that they would like to determine first whether there is user demand for such a service. The service is also being provided in several non-GÉANT countries, in most cases through a manual provisioning process executed by the NOC. SURFNet of the Netherlands uses OpenDRAC as its provisioning tool.

Major expected developments reported by NRENs include:

- In developed regions of the world, dark fibre networks are already in place and are being upgraded and extended to 10 Gb/s or multiples thereof. Some NRENs are preparing for 100 Gb/s. DWDM is reported by four NRENs;
- In several countries bordering on the EU, increased possibilities for international connectivity are acting as a catalyst for developments at the national level.

3.2 Network Operations Centres

A Network Operations Centre (NOC) is responsible for operating and monitoring a NREN's network and associated services. Some NRENs have separate centres for each of the various categories of services that they operate or for the users to which they provide them.

NOCs are a vital element in delivering a mission-critical service such as an NREN network, which entails handling an extensive range of services including physical infrastructure, network administration and network monitoring. Most NOCs have national coverage. They are responsible for national and international links, including those to other NRENs and to GÉANT, to Internet exchange points and to the commercial Internet. Manning such centres can be a major challenge, and different NRENs take different approaches to staffing, as shown by Tables 3.2.1 and 3.2.2 (right). In addition to the NOCs listed, GÉANT and NORDUnet also have NOCs, with 17 and 19 staff, respectively.

TERENA's NOC Task Force, TF-NOC, conducted its own, much more detailed survey of NOC operations in the summer of 2011. The results of that survey are publicly available through **www.terena.org/activities/tf-noc**.

Table 3.2.1 – NOC staff, GÉANT partner countries

NRENs directly employing NOC staff	NOC staff employed by NREN in-house[1]
Austria	4
Croatia	17
Cyprus	1
Estonia	2
Finland	5
Germany	9
Greece	15
Hungary	5
Ireland	16
Italy	8
Latvia	5
Lithuania	10
Luxembourg	3
Montenegro	4
Norway	19

NRENs directly employing NOC staff	NOC staff employed by NREN in-house[1]
Portugal	9
Romania	6
Slovenia	5
Switzerland	14
Turkey	6

NRENs outsourcing staff	NOC staff outsourced by NREN
Denmark	6
France	7
Israel	1.5
Netherlands	16
Slovakia	3.5
Sweden	14

NRENs using a combination of in-house/outsourced staff	NOC staff employed by NREN in-house[2]	NOC staff outsourced by NREN	Total NOC staff
Belgium	4.48	0.4	4.88
Bulgaria	2	3	5
Czech Republic	1	4.5	5.5
Iceland	0.2	0.8	1
Spain	6	4	10
United Kingdom	18	35	53

[1] All figures are in full-time equivalents (FTE).

Table 3.2.2 – NOC staff, other countries

NRENs directly employing NOC staff	NOC staff employed by NREN in-house[1]
Algeria	6
Australia	10
Azerbaijan	3
Bosnia/Herzegovina	4
Canada	5
Georgia	3
Kazakhstan	19
Moldova	5
Morocco	3
Russian Federation	12
Serbia	7
Tajikistan	8
Uzbekistan	6

NREN's using a combination of in-house/outsourced staff	NOC staff employed by NREN in-house[2]	NOC staff outsourced by NREN	Total NOC staff
Belarus	4	1	5
Brazil	26	34	60
Korea	10	10	20
Malaysia	3	1	4
New Zealand	0	2	2
Taiwan	19	6	25

[2] All figures are in full-time equivalents (FTE).

3.3 PoPs and routing

The number of PoPs (points of presence) on a network is one indicator of the amount of resources that the NREN needs in order to maintain the network. A PoP is defined as a point on the NREN backbone which can connect client networks or aggregations of client networks, such as MANs or external networks.

There are various ways in which a network can be built, leading to different requirements in terms of the number of PoPs. Thus, Germany's (i.e. DFN's) network – with 54 optical PoPs and 54 locations where core routing is undertaken – has an architecture that is quite different to that of the Netherlands (i.e. SURFnet) — with its 344 optical PoPs but only two locations where core routing is undertaken. For this reason, statistics indicating the total number of PoPs in Europe are not as meaningful as might be imagined.

Table 3.3.1 – Numbers of PoPs

Country	No. of PoPs	No. of PoPs providing optical connectivity	No. of PoPs where L3 routing is provided
GÉANT partner countries			
Austria	20	20	
Belgium	22	22	20
Bulgaria	14		
Croatia	820	774	27
Cyprus	2	0	0
Czech Republic	41	19	41
Denmark	20	19	2
Estonia	16	4	
Finland	72	72	11
France	60	47	
Germany	54	54	54
Greece	42	30	9
Hungary	114	114	63
Iceland	13	0	13
Ireland	22	13	0

Table 3.3.1 – continued

Country	No. of PoPs	No. of PoPs providing optical connectivity	No. of PoPs where L3 routing is provided
GÉANT partner countries			
Israel	2	0	0
Italy	58	16	36
Latvia	5	1	0
Lithuania	48	6	
Luxembourg	13	6	13
Macedonia, FYRo	1	1	
Malta	2	2	2
Montenegro	6	6	0
Netherlands	344	344	2
Norway	51	28	
Poland	33	33	0
Portugal	12	12	2
Romania	108	52	44
Slovakia	34	34	20
Slovenia	45	45	45
Spain	20	0	0
Sweden	25	23	8
Switzerland	35	35	45
Turkey	3	0	
United Kingdom	21	21	62
Other countries			
Algeria	10	10	
Azerbaijan	2	2	2
Belarus	28	22	10
Bosnia/Herzegovina	7	7	2
Georgia	11	10	10
Moldova	42	20	15

Table 3.3.1 – continued

Country	No. of PoPs	No. of PoPs providing optical connectivity	No. of PoPs where L3 routing is provided
Other countries			
Morocco	15	12	
Russian Federation	15	4	
Serbia	54	54	
Ukraine	32	32	
Australia	60	60	30
Brazil	27	24	0
Canada	25	25	25
El Salvador	5	5	
Kazakhstan	20	12	20
Korea	18	18	
Kyrgyzstan	1	1	
Malaysia	5	0	0
New Zealand	23	0	12
Taiwan	16	16	16
Tajikistan	12	12	12
Turkmenistan	5	5	
Uzbekistan	27	3	

With the *Compendium* questionnaire, we collected data on the number of NREN-managed circuits that carry production traffic. This is one indicator of the overall size and complexity of a network.

As Table 3.3.2 (right) shows, NRENs differ considerably in this respect. The differences in the number of managed circuits reflect differences in network architecture and number of clients connected. In this table, increases or decreases in the number of managed circuits by at least 25% since 2010 are highlighted in colour.

Table 3.3.2 – Number of managed circuits

Country	No. of client institutions	No. of managed circuits, 2011	No. of managed circuits, 2010
GÉANT partner countries			
Austria	116	24	24
Belgium	191	152	148
Bulgaria	2094	30	30
Croatia	1546	820	769
Cyprus	12		
Czech Republic	323	71	62
Denmark	38	100	22
Estonia	258	20	20
Finland	75	240	145
France	1300	125	
Germany		141	134
Greece	15036	200	490
Hungary	434	119	48
Iceland	24	22	18
Ireland	4048	450	569
Israel	17	16	16
Italy	391	81	81
Latvia	40	40	40
Lithuania	870	200	200
Luxembourg	246	80	80
Macedonia, FYRo	75	25	25
Malta	6		17
Montenegro	25	31	31
Netherlands	141	154	336
Norway	167	245	245
Poland		108	38
Portugal	71	85	85
Romania	685	281	55
Slovakia	421	40	35

Table 3.3.2 – continued

Country	No. of client institutions	No. of managed circuits, 2011	No. of managed circuits, 2010
GÉANT partner countries			
Slovenia	969	1294	1341
Spain	424	67	67
Sweden	82	220	210
Switzerland	64	56	50
Turkey	838	164	160
United Kingdom	849	1200	1009
Other countries			
Algeria	117	10	3
Azerbaijan	98	53	52
Belarus	27	1	
Bosnia/Herzegovina	74	10	10
Georgia	158	153	153
Moldova	1690	28	28
Morocco	115	24	20
Russian Federation	64	4	
Serbia	62		
Ukraine	580	40	
Australia	34	2	4
Brazil	73	50	50
Canada	103	35	34
El Salvador	490	19	
Kazakhstan		175	160
Korea	66	20	2
Kyrgyzstan	536	97	79
Malaysia	68		10
New Zealand	131	17	
Taiwan	5		
Tajikistan	2481	34	34
Turkmenistan	111	1	
Uzbekistan		6	6

3.4 Core capacity on the network

The term 'core usable backbone capacity' means the typical core capacity of the linked nodes in the core. Some NRENs have dark fibre with a very high theoretical capacity; in such cases, we requested data on the usable IP capacity.

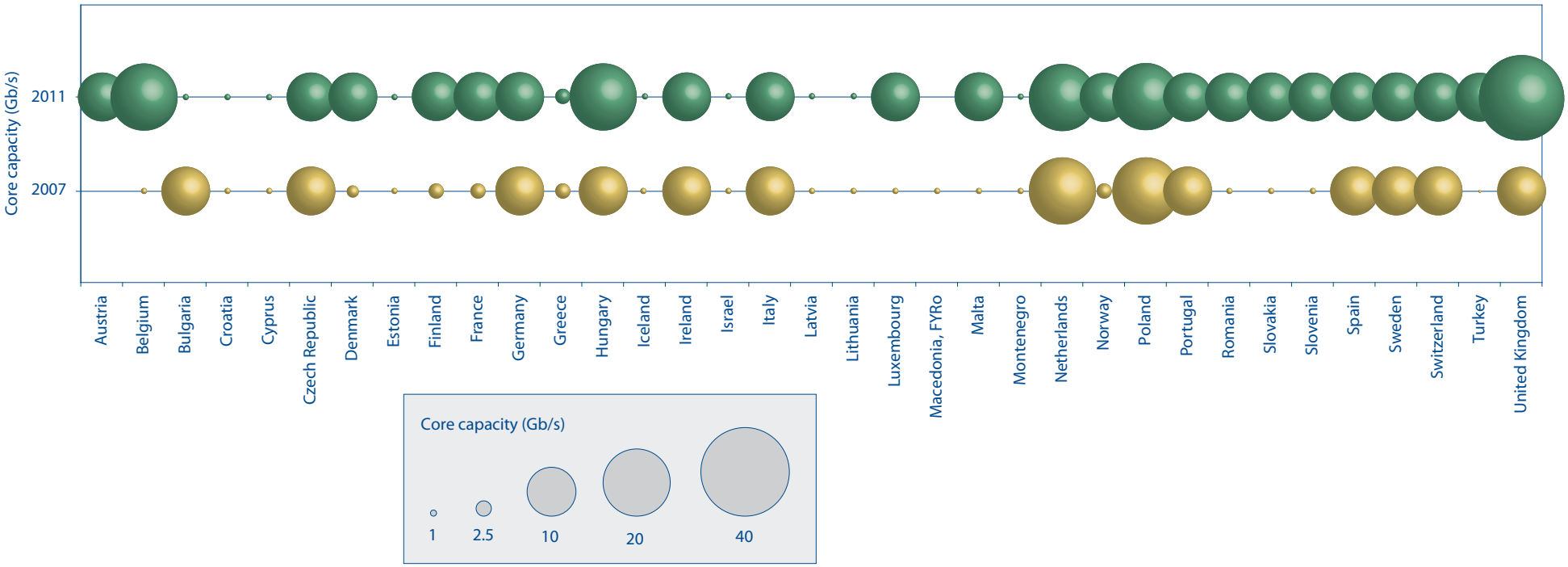
Graph 3.4.1 (below) shows how network capacities evolved in the period 2007-2011. In addition, Section 3.6 shows that many NRENs now have several point-to-point circuits and lightpaths, which offer additional capacity that is not usually included in normal traffic statistics.

In most GÉANT partner countries, the typical core capacity is now 10 Gb/s, though some NRENs have reached 20 or even 40 Gb/s. 10 Gb/s is also the median capacity, up from 2 Gb/s in 2007. As many NRENs in this region have access to dark fibre (see Section 3.7), which is potentially able to handle high capacities, they can increase capacity easily and economically whenever required. In 2007, the typical capacity was 2.5 Gb/s and the transition to dark fibre had not yet taken place on a large scale.

In the non-GÉANT countries, the trend that was visible last year continues: they have profited from the introduction of affordable Gigabit Ethernet technology.

Network capacity is not growing linearly. Comparing the growth in core capacity with the growth in overall traffic – documented in Section 4.3 – reveals that, nevertheless, on average these two trends keep pace with each other. In the period 2007-2011, the average growth of core capacity in the GÉANT partner countries was 50% per annum. In the same period, average growth of traffic on the GÉANT backbone was 40.6% per annum.

Graph 3.4.1 – Core capacity on the networks, 2007-2011, GÉANT countries



3.5 External connectivity: total external links

The NRENs covered by this edition of the *Compendium* were asked to list all their external connections as of January 2011.

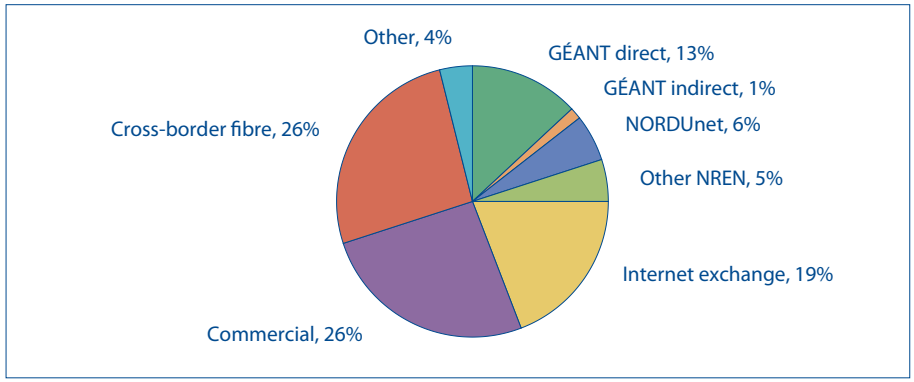
Please note that the Nordic NRENs (Funet of Finland, RHnet of Iceland, SUNET of Sweden, UNINETT of Norway and UNI•C [Forskningsnettet] of Denmark) share their external connections through NORDUnet.

In general, connections to GÉANT and to other NRENs carry research and education traffic, while peerings and other connections convey traffic to and from the general Internet. Research and education traffic may consist of highly specialised data and is often transmitted in huge volumes within very short time-frames; for example, real-time observational data from a radio telescope, which must be transmitted over large distances for pre-processing and storage. As high traffic peaks can be expected on such links, they must be dimensioned to accommodate them; it is not unusual to see a flow of 1 Gb/s generated by a single high-end researcher. Thus, the average volume of traffic is not a reliable indicator of the required capacity of the link.

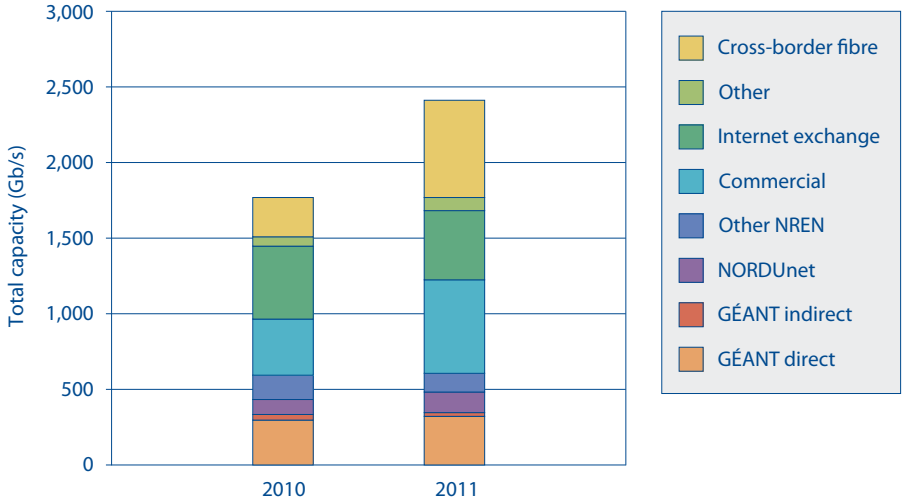
In contrast, traffic to and from the general Internet tends to be aggregated and smoothly varying. It comprises a large number of small-to-medium data flows, which combine to produce a fairly predictable traffic pattern. Therefore, the required capacity of the link can be reliably related to the average flow of data. Note that in Graph 3.5.1 these two distinct categories of connections are combined.[3]

In general, this means that connections not only to the European academic backbone network (i.e. GÉANT) but also to the general Internet are crucially important to NRENs. Graph 3.5.1 (right), which represents the average situation for all GÉANT partner NRENs, illustrates that, currently, connections via cross-border fibre and to the commercial Internet jointly account for over 50% of the total external connectivity. The next largest categories are connections to Internet exchanges and connections to GÉANT and NORDUnet, which together account for 38%. Compared to the previous year, total capacity has grown, but not equally in all connection categories, as Graph 3.5.2 illustrates. The areas of greatest expansion have been cross-border fibre and connections to commercial Internet providers.

Graph 3.5.1 – Capacity of NREN external connections, GÉANT partner countries



Graph 3.5.2 – Capacity of NREN external connections, GÉANT partner countries, 2010 and 2011



[3] A more extensive discussion of traffic load levels and patterns is provided in the 2008 edition of the *Compendium*, pp. 51-55.

It should be noted that there are large differences between NRENs, as was illustrated in greater detail in the 2009 edition of the *Compendium*. Also note that this graph does not include the additional international point-to-point circuits (other than the IP circuits already covered) that some GÉANT partner NRENs operate, mostly for specific projects.

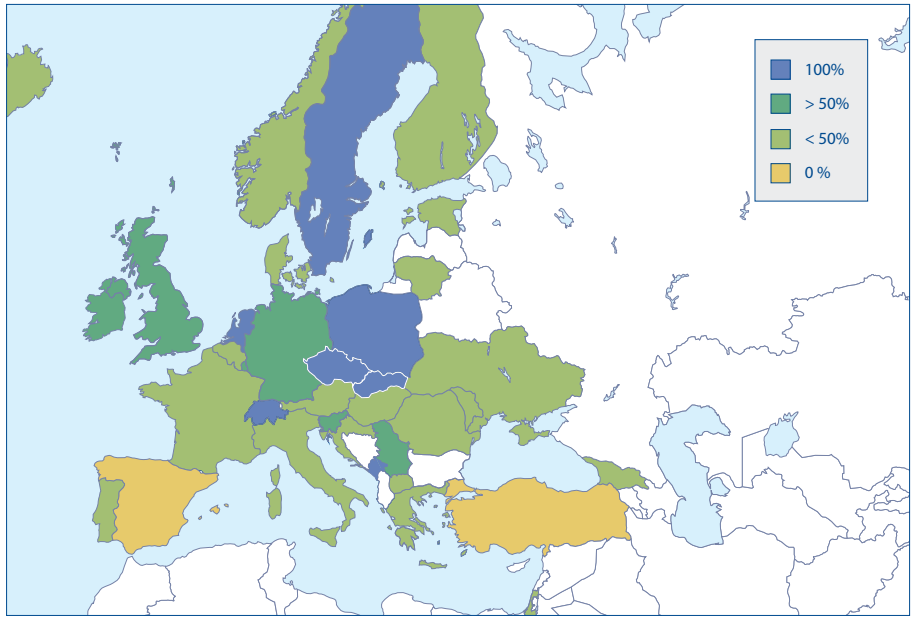
3.6 Dark fibre

Some NRENs own, have indefeasible rights of use (IRUs)[4] to, or lease dark fibre, and can therefore decide what technology and speeds to use on it. The NRENs covered by this edition of the *Compendium* were asked whether they currently own, or have IRUs to, dark fibre, or plan to acquire it within the coming two years.

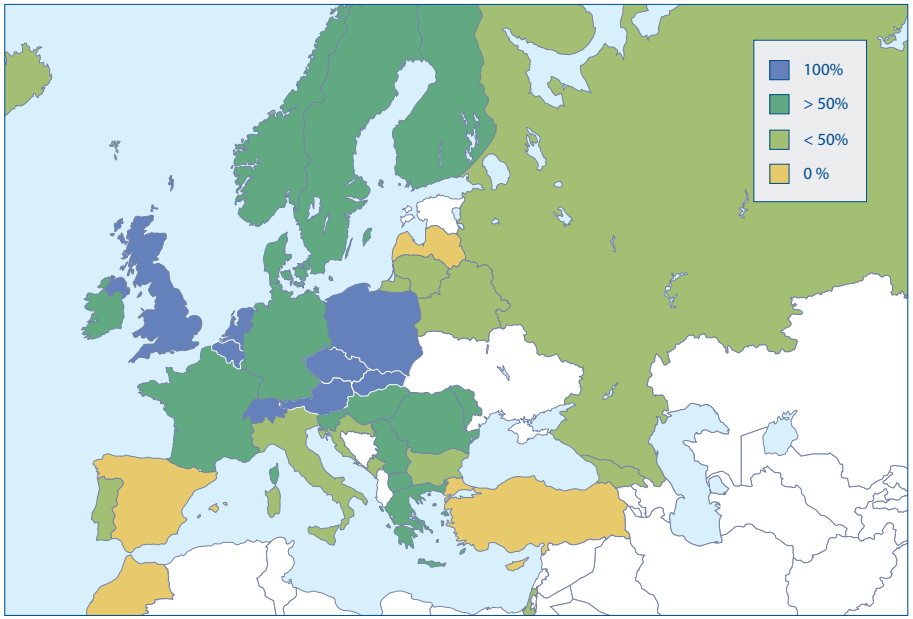
The NRENs were also asked to state approximately what percentage of their backbone is accounted for by dark fibre.

Maps 3.6.1 and 3.6.2[5] (below) illustrate the rapid developments in dark fibre in recent years. Many, though not all, NRENs predict a further increase in the percentage of their network accounted for by dark fibre by 2012. Note that, at the start of 2011, Spain did not yet have dark fibre on its backbone, but was engaged in a major upgrading exercise, deploying more than 10 000 km of dark fibre during the year. It should be noted that dark fibres may not always be the best or the cheapest solution for NRENs. By the time current IRU contracts expire, conditions may have changed and it may be appropriate for some NRENs to consider other options as well. Table 3.6.3 shows that although, on balance, NRENs generally added dark fibre in 2010, some fibre was decommissioned as well.

Map 3.6.1 – Dark fibre on NREN backbones, 2007



Map 3.6.2 – Dark fibre on NREN backbones, 2011



[4] Effective long-term leasing (temporary ownership) of a portion of the cable's capacity. The distinction between an IRU and a lease is becoming less clear; therefore, in this section these two categories have been combined.

[5] Concept developed by RedIRIS, Spain.

Note that, for certain countries that did not respond in the year in question, data from the previous year was used instead.

Table 3.6.3 – Dark fibre on NREN backbones, 2011

Country	Total length of dark fibre (km)	Length added in 2010 (km)	Length decommissioned in 2010 (km)
GÉANT partner countries			
Austria	4,500	0	0
Belgium	1,990	121	20
Croatia	360	0	0
Czech Republic	5,090	490	0
Denmark	2,000	100	0
Estonia	250	0	0
Finland	3,750	50	0
France	11,012	2,001	638
Germany	10,500	500	0
Greece	8,950	536	30
Hungary	3,200	3,100	0
Iceland	190	10	0
Ireland	2,600	100	0
Israel	15	0	0
Italy	1,000	500	
Luxembourg	300	80	0
Netherlands	10,654		
Norway	8,200	100	0
Poland	7,257	539	0
Portugal	1,000	20	0
Romania	4,838	0	0
Slovakia	2,100	50	0
Slovenia	1,623	366	341
Sweden	7,800	200	0
Switzerland	2,981	53	0
Turkey	145	145	
United Kingdom	8,021	0	0

Table 3.6.3 – continued

Country	Total length of dark fibre (km)	Length added in 2010 (km)	Length decommissioned in 2010 (km)
Other countries			
Azerbaijan	35		
Belarus	18	12	0
Bosnia/Herzegovina	700	10	0
Georgia	70	0	0
Russian Federation	460	0	0
Serbia	2,150	0	0
Australia	61,600	1,000	0
Brazil	1,167	274	0
New Zealand	60	500	10
Taiwan	834	0	0
Tajikistan	70	10	0
Turkmenistan	80	30	
Uzbekistan	12	0	0

3.7 Cross-border dark fibre

A number of countries have already installed or are planning to install cross-border dark fibre links to neighbouring NRENs. Cross-border dark fibre "is optical fibre dedicated to use by a single organisation — where the organisation is responsible for attaching the transmission equipment to 'light' the fibre".[6] Table 3.7.1 provides an overview of current cross-border dark fibre links. Table 3.7.2 shows which new links NRENs currently plan to install. As is clear from the table, this trend is set to continue in the next few years. Outside of Europe, RNP of Brazil reported that it already has a dark fibre link with Argentina and is planning to install such links with Paraguay and Uruguay.

Maps 3.7.3 and 3.7.4 present the same information schematically. Note that the links shown do not necessarily correspond to the actual geographical routes.

[6] *Networks for Knowledge and Innovation: A strategic study of European research and education networking*, Summary Report on the SERENATE studies, IST-2001-34925, p. 28, www.serenate.org/publications/d21-serenate.pdf

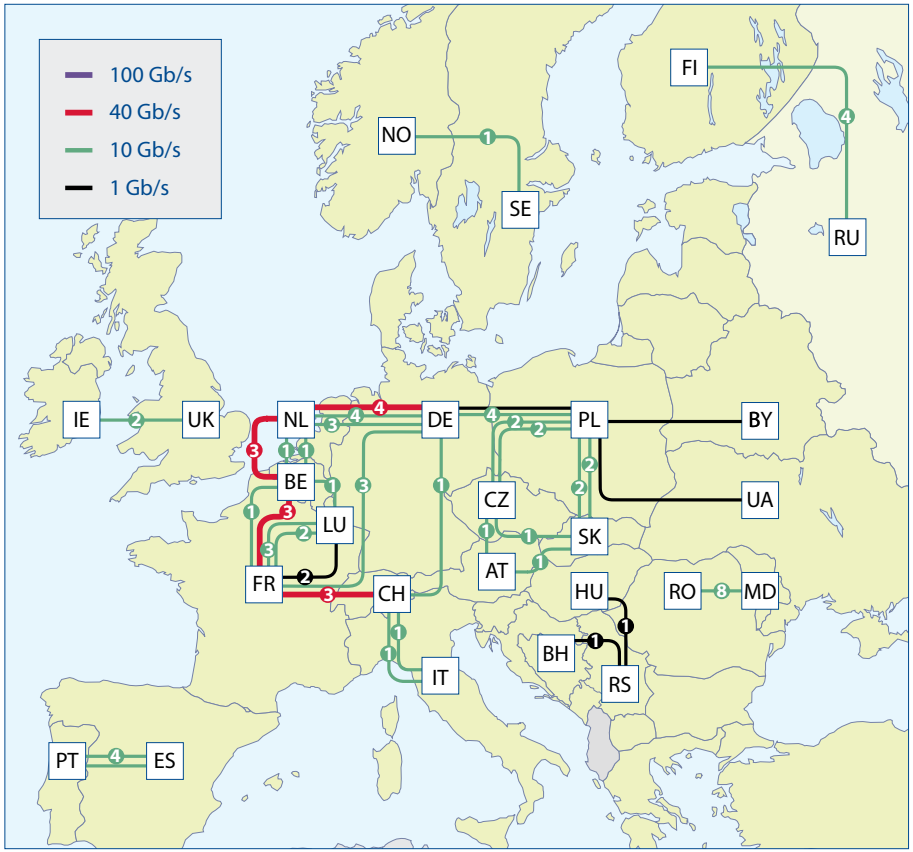
Table 3.7.1 – Cross-border dark fibre (current)

NREN	NREN	Current	Start date	Current capacity (Gb/s)	No. of lambdas
ACOnet	SANET	Vienna (AT) - Bratislava (SK)	2002	10	1
ACOnet	CESNET	Vienna (AT) - Brno (CZ)	2006	10	1
Belnet	SURFnet	Amsterdam (NL) - Brussels (BE)	11/2009	10	1
Belnet	RENATER	Brussels (BE) - Paris (FR)	01/2011	10	1
Belnet	RESTENA	Arlon (BE) - Esch (LU)	01/2011	10	1
CESNET	SANET	Brno (CZ) - Bratislava (SK)	2005	10	1
CESNET	PIONIER	Ostrava (CZ) - Poznan (PL)	2005	10	2
DFN	PIONIER	Guben (DE) - Gubin (PL)		1	-
DFN	SWITCH	Karlsruhe (DE) - Basel (CH)	2008	10	1
FCCN	RedIRIS	Lisbon (PT) - Badajoz (ES)	2009.06.04	10	4
Funet	e-ARENA	Espoo (SF) - St. Petersburg (RU)	2009	10	4
GARR	SWITCH	Milan (IT) - Manno (CH)	23/05/2006	10	1
GARR	SWITCH	Milan (IT) - Manno (CH)	01/01/2011	10	1
HEAnet	JANET(UK)	Dublin (IE) - Belfast (UK)	2007	10	2
NIIF/ HUNGARNET	AMRES	Szeged (HU) - Subotica (RS)	2005	1	1
PIONIER	CESNET	Cieszyn (PL) - Cesky Tesin (CZ)		10	2
PIONIER	SANET	Zwardoń-Skalite (PL) - Žilina (SK)	Oct 2007	10	2
PIONIER	URAN	Hrebenne (PL) - Lviv (UA)	Dec 2008	1	-
PIONIER	BASNET	Kuźnica Białostocka (PL) - Grodno (BY)	Aug. 2010	1	-
PIONIER	DFN	Słubice (PL) - Frankfurt /O (DE)	2010	10	1
PIONIER	SURFnet/ NORDUnet	Poznán (PL) - Hamburg (DE)	2010	10	3
RedIRIS	FCCN	Vigo (ES) - Porto (PT)	2011	10	-
RENAM	RoEduNet	Chisinau (MD) - Lasi (RO)	end of 2009	10	8
RENATER	DFN	Strasbourg (FR) - Kehl (DE)	2007	10	3
RENATER	RESTENA	Nancy (FR) - Esch/Alzette (LU)	2010	10	2
RENATER	RESTENA	Thionville (FR) - Esch/Alzette (LU)	Sept. 2010	10	3
RENATER	RESTENA	Longwy (FR) - Esch/Alzette (LU)	end 2010	1	2
SANET	PIONIER	Žilina (SK) - Bielsko - Biała (PL)	Jan. 2008	10	2
SARNET	AMRES	Karakaj (BH) - Sabac (RS)	2006	1	1
SUNET	UNINETT	Kiruna (SE) - Narvik (NO)	2011	10	1
SURFnet	DFN	Amsterdam (NL) - Hamburg (DE)	2007	40	4
SURFnet	DFN	Maastricht (NL) - Aachen (DE)	2007	10	4
SURFnet	DFN	Enschede (NL) - Muenster (DE)	2007	10	3
SURFnet	SWITCH	Amsterdam (NL) - Brussels - Paris - Geneva (CH)	2010	40	3
SURFnet	Belnet	Amsterdam (NL) - Brussels (BE)	2011	10	1

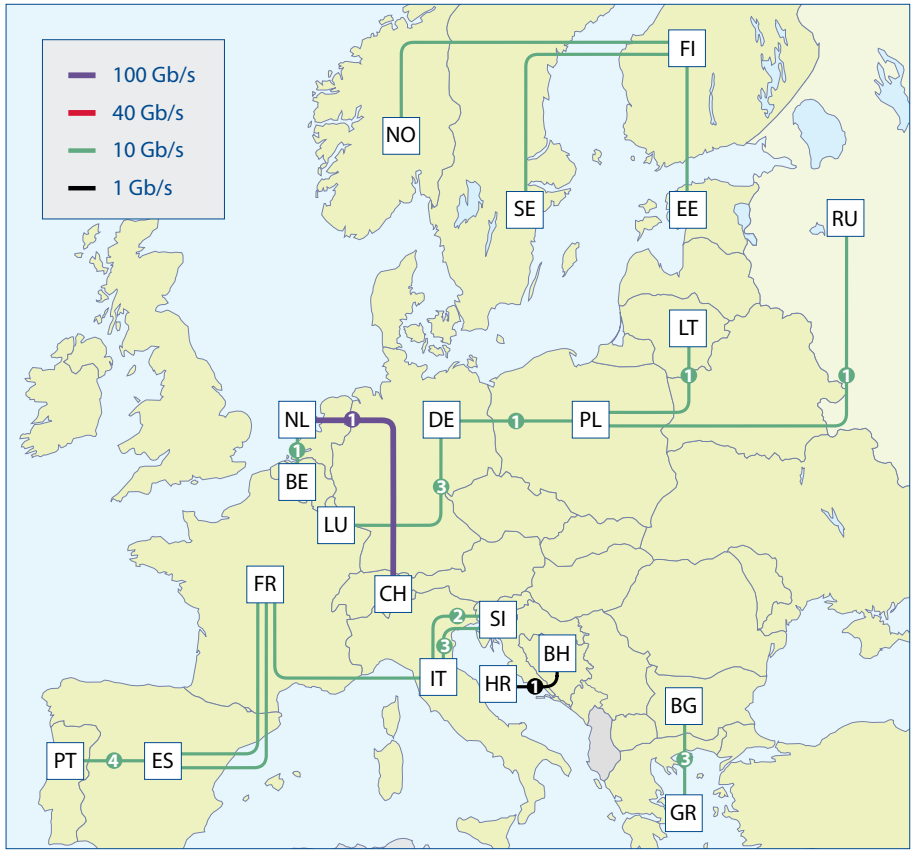
Table 3.7.2 – Cross-border dark fibre (planned)

NREN	NREN	Planned	Start date	Capacity (Gb/s)	No. of lambdas
Belnet	SURFnet	Hasselt (BE) - Maastricht (NL)	Jan. 2012	10	1
Funet	EENet	Helsinki (FI) - Tallinn (EE)	2012	10	-
Funet	SUNET	Kemi (FI) - Luleå (SE)	2012	10	-
Funet	UNINETT	Sodankylä (SF) - Utsjoki (NO)	2012	10	-
RENATER	GARR	Modane (FR) - Bardonecchia (IT)			-
GRNET S.A.	BREN	Athens (GR) - Sofia (BG)	2012	10	3
GARR	ARNES	Trieste (IT) - Sezana (SI)	31/10/2011	10	2
RESTENA	DFN	Saarbrücken (DE) - Esch/Alzette (LU)	2011	10	3
SURFnet	SWITCH	Amsterdam (NL) - Geneva (CH)	2011	100	1
PIONIER	LITNET	Ogrodniki (PL) - Kaunas (LT)	2012	10	1
PIONIER	e-ARENA	Gronowo (PL) - Mamonowo (RU)	2012	10	1
PIONIER	DFN	Kołbaskowo (PL) - Prenzlau (DE)	2012	10	1
FCCN	RedIRIS	Porto (PT) - Vigo (ES)	Jan. 2011	10	4
ARNES	GARR	Sežana (SI)- Trieste (IT)	end of 2011	10	3
RedIRIS	RENATER	Barcelona (ES) - Montpellier (FR)	approx.2013	10	-
RedIRIS	RENATER	Bilbao(ES)-Bordeaux (FR)	approx.2013	10	-
SARNET	CARNet	Gradiska (BH)-Zagreb (HR)	2012	1	1

Map 3.7.3 – Cross-border dark fibre, current
(the numbers in the map indicate the number of lambdas)



Map 3.7.4 – Cross-border dark fibre, planned
(the numbers in the map indicate the number of lambdas)



3.8 Bandwidth on Demand

Currently, researchers in fields such as astronomy, geology, physics and environmental science often need dedicated channels to transport data between varying locations at high rates with guaranteed levels of service.

Internet Protocol (IP) networks provide always-on services for data transfer but cannot guarantee quality (e.g. elimination of data loss at bottlenecks) or resources for bulk transfers with time constraints (e.g. streaming of large amounts of data from different locations to a cluster for real-time correlation). On the other hand, fixed circuits interconnecting end-points participating in demanding research applications are costly and often result in under-utilisation of e-Infrastructures.

For certain use cases, a dynamic circuit service addresses the limitations of IP networks and fixed circuits by isolating resources over existing infrastructures, reserving them, and providing quantity and quality guarantees at the level required, for the time period required and between the end-points involved. As soon as a circuit's resources are no longer necessary, they are released for another potential transfer between different end-points utilising the same resources.

In the context of GÉANT, a system is being developed that is to provide a user-friendly interface for instantiating dynamic circuits over global research and education network infrastructures. In addition, individual NRENs are working in this area.

In our questionnaire for this edition of the *Compendium*, we asked NRENs whether they currently provide such a service and, if so, whether they offer it through manual provisioning, via a provisioning tool, or in some other way. We also asked whether online monitoring tools or other on-line information is available.

The results are summarised in Table 3.8.2 (right). As Graph 3.8.1 (right) shows, 26% of the GÉANT partner NRENs currently offer such a service or are planning to do so. A further 17% indicate that they would like to determine first whether there is user demand for such a service, which is also being offered in several non-GÉANT countries.

In most cases, the service is provided through a manual provisioning process conducted by the NOC. SURFNet of the Netherlands uses OpenDRAC as its provisioning tool.

Graph 3.8.1 – Bandwidth on Demand, GÉANT partner NRENs

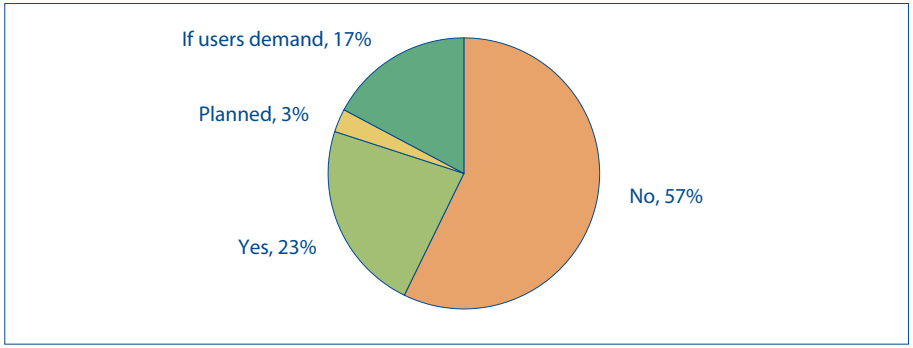


Table 3.8.2 – Bandwidth on Demand

Country	Service offered?	Method and description		Monitoring or other on-line information?
GÉANT partner countries				
Denmark	if users demand	manual		yes
Finland	if users demand			
Germany	yes	other[8]		yes
Greece	yes	manual		yes
Hungary	yes	manual		yes
Ireland	yes	manual		no
Italy	if users demand			
Malta	if users demand			
Netherlands	yes	tool	OpenDRAC (www.opendrac.org)	no
Norway	yes	manual		no
Poland	planned			
Portugal	yes	manual		no
Slovenia	yes	manual		no
Spain	if users demand			
United Kingdom	if users demand	other		
Other countries				
Russian Federation	yes	manual		yes
Serbia	yes	manual		yes
Australia	yes	manual		yes
Canada	yes	manual		yes
Brazil	yes	manual	We are developing a service using tools like OSCARS.	
Taiwan	yes	manual		yes
Korea	yes	Site Manager and Metro Ethernet Manager of Ciena, OpenDRAC.		no
Kyrgyzstan	yes	manual		no
Uzbekistan	planned			

[8] DFN provides Lambda-based P2P-connections with 'manual provisioning'.

3.9 Major expected network developments

The NRENs covered by this edition of the *Compendium* were asked to outline major initiatives relating to the development of their underlying network that they expect to realise within the next two to five years. Several NRENs that did not respond to this question did provide information on major changes in their organisations; these are listed in Appendix A.

Table 3.9.2 provides a general insight into expected major developments of networks in the various countries in Europe and other continents. The expected developments reported by NRENs include:

- In developed regions of the world, dark fibre networks are already in place and are being upgraded and extended to 10 Gb/s or multiples thereof. Some NRENs are preparing for 100 Gb/s. DWDM is reported by a number of NRENs;
- For several EU neighbour countries, increased possibilities for international connectivity are acting as a catalyst for developments at the national level.

Figure 3.9.1 illustrates the major expected network developments in the form of a Wordle chart.

Figure 3.9.1 – Major expected network developments as a Wordle chart

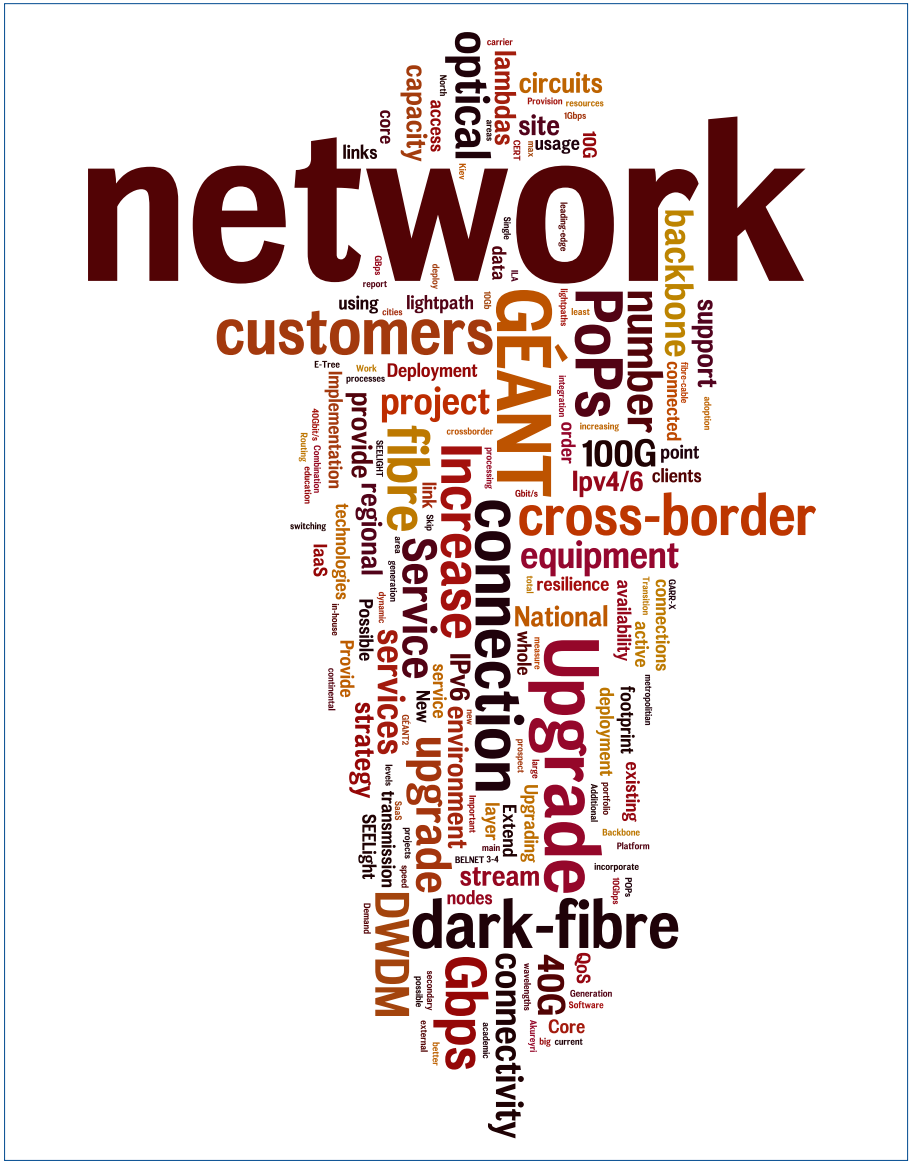


Table 3.9.2 – Major expected network developments [lightly edited for consistency]

Country	Developments	Time frame[9]	Confidence
GÉANT partner countries			
Belgium	Belnet will put the demarcation point at the customer site by entering the customer site with both connectivity and active equipment (CPE).	2011	Quite certain
	Belnet will use active equipment at the customer's site to measure and report Service Level Parameters.	2012	Quite certain
	Belnet wants to deploy smaller optical rings by connecting R&D customers around big cities.	2012	Quite certain
	Belnet will implement QoS on: - the backbone; - the access network between the customer and the BELNET PoP.	2011	Quite certain
	Belnet will enlarge his services portfolio with a Fiberchannel service and will provide 100 Gb/s lightpaths.	2012	Quite certain
Bulgaria	SEELIGHT Project. Gives the prospect of providing cross-border dark-fibre links and dark fibre to at least part of the National Backbone.	1	Quite certain
Croatia	QoS.	2011	Quite certain
	Optical switching.	2012	Likely
Cyprus	Upgrade the GÉANT connection up to 2.5 Gb/s.	1	Quite certain
Czech Republic	Migration to 40 Gb/s.	2	Quite certain
Denmark	10 -> 100 Gb/s Core.	5	Quite certain
Finland	Extend the coverage of the DWDM optical network and upgrade the existing multi-degree DWDM nodes to WSS (PXC).	2	Quite certain
	Expand the availability and usage of backup customer connections. Provide better availability of 10 Gb/s connections to the customers.	2	Quite certain
	Introduce dynamic lightpath services to complement the current static lightpath service.	3	Quite certain
Germany	100 Gb/s, flexible Lambda switching.	2-3	Uncertain

[9] Year or number of years.

Table 3.9.2 – continued

Country	Developments	Time frame[9]	Confidence
GÉANT partner countries			
Greece	40/100 Gb/s internal links.	2	Quite certain
	Cross-border fibre to Bulgaria.	1	Quite certain
	Dynamic creation and maintenance of optical paths with capacities of 1/10/40/100 Gb/s.	2	Quite certain
	Cross-border fibre to Turkey.	3	Uncertain
	Provision of E-Line, E-Lan and E-Tree services in the carrier network.	1	Quite certain
Hungary	Major network developments within the frameworks of our NDP projects.	2010-2012	Quite certain
Iceland	10 Gb/s build-out in Reykjavik area.	0.5	Quite certain
	1Gb/s connection to Akureyri.	1	Likely
Ireland	Upgrading of existing DWDM network to ROADM.	2 years	Quite certain
	Possible support of WiMAX networks on campus networks.	1 - 3 years	Uncertain
	Possible connection of large number of sensors to network.	1 - 3 years	Likely
	Skip 40G, using n x 10G while waiting for 100 G.	1 - 2 years	Quite certain
	Virtualisation of network resources using IaaS (Infrastructure as a Service) framework. This can incorporate BoD (Bandwidth on Demand).	1 - 3 years	Quite certain
	Work on the integration of virtualisation of network and services (combination of IaaS, PaaS (platform) and SaaS (software)).	1 - 3 years	Quite certain
	A three-stream strategy on IPv4/6 environment: a. IPv4 depletion processes (1 year / ongoing).	1 - 5 years	Quite certain
	b. Fully standalone IPv6 network (1 – 2 years).	1 - 5 years	Quite certain
	c. Clients on IPv6 (3-4 years).	1 - 5 years	Quite certain
	Service resilience (path, PoP, power and equipment) for clients. (Largely completed).	now	Quite certain
	Service resilience at the optical / transmission layer, through no single point of failure for connectivity.	1 - 3 years	Likely
	National centralised data storage for clients.	1 - 3 years	Quite certain
	National central data centre for the education and research community.	1 - 3 years	Quite certain

Table 3.9.2 – continued

Country	Developments	Time frame[9]	Confidence
GÉANT partner countries			
Israel	Core network upgrade to 10 Gb/s.	1	Quite certain
	Upgrade connectivity to GÉANT to 10 Gb/s.	1.5	Quite certain
Italy	Deployment of next-generation national network (GARR-X) – ownership of dark fibre at backbone and access levels – adoption of leading-edge multiplexing technologies (DWDM), in order to optimize their usage – support of 40 Gb/s, 100 Gb/s.	1	Quite certain
Latvia	GÉANT connection upgrade.	1	Likely
	Dark fibre to Estonia, Lithuania.	4	Uncertain
Lithuania	Upgrade of the whole ring speed to 10 Gb/s with 1 Gb/s lambdas as backups.	2011	Quite certain
	CBF connection with Poland.	2012	Uncertain
Macedonia, FYRo	SEELight project.	2012	Likely
	Additional 155 Mb/s.	2011	Quite certain
Montenegro	Upgrade of link/capacity enhancement.	2	Quite certain
	Connection private universities.	2	Likely
	Upgrade security level of academic network.	1	Quite certain
	Implementation of IPv6.	1	Quite certain
Netherlands	Transition of SURFnet network to Next Generation Ethernet.	2011-2012	Quite certain
	Renewal of photonic layer of SURFnet network.	2013-2014	Uncertain
Norway	Upgrade to lambda capability between mainland and Longyearbyen (Svalbard). 2*1400 km.	2012	Quite certain
	Cross-border fibre from Northern Norway (Finnmark county) to FUNET.	2012	Likely
	New fibre cable between Longyearbyen and Ny-Ålesund on Svalbard. 2*260km.	2013	Quite certain
Poland	Increase capacity to GÉANT Plus.	2011	Likely
	Increase capacity to DANTE World Service.	2011	Likely
	Extend new DWDM system (max. 80 lambdas) footprint to the whole network.	2011	Quite certain

Table 3.9.2 – continued

Country	Developments	Time frame[9]	Confidence
GÉANT partner countries			
Portugal	The major initiative is the enlargement of the dark-fibre footprint to those institutions in the interior of continental Portugal.	3	Likely
	Conclusion of the second CBF link to Spain, in the North.	1	Quite certain
	Single fibre optical transmission.	2	Quite certain
Romania	– core upgrade to 40 Gb/s – 100 Gb/s.	2	Quite certain
	– cross-border with Serbia, Hungary, Bulgaria.	3	Quite certain
Slovakia	Increase the number of POPs to a total of 79 in order to serve secondary schools in all regional centres.	4	Quite certain
	100-gigabit ethernet in the backbone.	5	Quite certain
Spain	New RedIRIS backbone network based on dark-fibre deployment and TROADM technology. More than 55 add/drop PoPs and 108 ILA sites. More than 10 500km of fibre deployment to end during summer 2011.	in use during 2011	Quite certain
	Important cut (approx. 50%) in the number of PoPs providing L3 Routing.	3Q 2011	Quite certain
	Provide wavelengths to the regional networks to support their own network and project requirements.	3Q 2011	Quite certain
Switzerland	100 Gb/s lambdas between certain PoPs.	2012	Likely
Turkey	Dark fibre installation in metropolitan areas .	2	Quite certain
United Kingdom	Upgrade of core infrastructure.	2013	Quite certain
	All regional networks to be managed in-house.	Within 5 years	Quite certain
Other countries			
Algeria	Direct to GÉANT2 – upgrade to STM4.	2	Likely
Belarus	Increase the capacity of the link to PIONIER up to 10 Gb/s.	2012	Likely

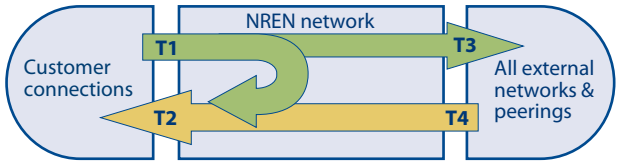
Table 3.9.2 – continued

Country	Developments	Time frame[9]	Confidence
Other countries			
Moldova	Upgrade connectivity to GÉANT.	2011-2012	Quite certain
	Upgrading internal network equipment in Chisinau MAN for processing and distribution of 10 Gb/s traffic in 5 main nodes of RENAM.	2011	Quite certain
	Elaboration and realization of detailed technical project of Eastern external connection to Ukraine .	2011	Likely
	GÉANT PoP in Chisinau organization.	2012	Quite certain
	Implementation of cross-border connection to the Ukrainian NREN (and to possible GÉANT PoP in Kiev).	2012	Likely
Serbia	SEELight project.	1	Quite certain
Brazil	Increase the number of PoPs connected by 10 Gb/s circuits from 15 to 24.	1-2 years	Quite certain
	Increase the total number of 10 Gb/s circuits from 24 to 35.	2-3 years	Likely
	Increase the number of PoPs connected by 10 Gb/s circuits from 24 to 27.	3-4 years	Likely
Kazakhstan	GÉANT connection.	1	Likely
	CERT set-up.	1	Likely
New Zealand	Evolve network architecture to KAREN 2.0.	1-3	Quite certain
	Move to dark fibre.	3	Quite certain
	Deployment of 40 Gb/s or 100 Gb/s technologies.	3	Likely

4 TRAFFIC

As in questionnaires sent out in previous years, the NRENs covered by this edition of the *Compendium* were requested to report their total annual traffic flows at the boundaries of their networks. The four flows they were asked to specify are defined in Diagram 4.0.1 (below).

Diagram 4.0.1 – Types of traffic flow



T1	All IP traffic from customer sites and the NREN.
T2	All IP traffic to customer sites and the NREN.
T3	All IP traffic to external networks.
T4	All IP traffic to the NREN from external networks.

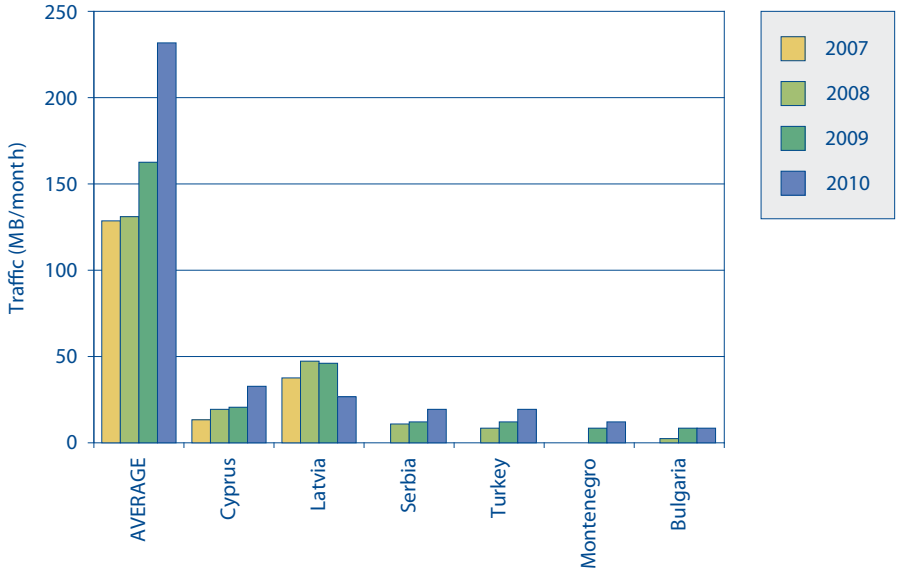
External traffic = all traffic to GÉANT, the commercial Internet, Internet Exchanges, etc. (i.e. composed of T3 and T4 above)

Section 4.1 gives an overview of the responses from the NRENs, as well as this year's traffic trends. Section 4.2 considers traffic in 2010, whereas Section 4.3 analyses traffic trends over the past five years. Section 4.4 gives information on NREN traffic per inhabitant. Section 4.5 looks at congestion. Section 4.6 examines the transition from IPv4 to IPv6. Finally, Section 4.7 focuses on lambda traffic.

4.1 Overview

Most of the NRENs that responded to the 2011 *Compendium* questionnaire reported the level of annual traffic flows at the point where they exchange traffic with external networks (T3 & T4); 76% of the NRENs also reported the level of annual traffic flows between their connected sites and their backbone network (T1 & T2). The T3 & T4 traffic levels are relatively easy to measure and record, as there are only a few points on the network to monitor. Graphs 4.2.1 (2010 traffic, T4 > 3500 TB) and 4.2.2 (2010 traffic, T4 < 3500 TB) represent all the national responses submitted in 2011. Comparison with data from previous years reveals that traffic continues to grow. Over the past seven years, the annual rate of growth has fluctuated (but always remained positive), averaging over 37%. In 2010, following a few years of declining growth rates, there was renewed acceleration in traffic. Lithuania was the country with the fastest traffic growth in terms of traffic per inhabitant.

Graph 4.1.1 – Traffic per inhabitant, <15% of European average



4.2 Traffic in 2010

Analysis of the available traffic data reveals substantial differences within Europe: traffic per inhabitant in Bulgaria, Cyprus, Latvia, Montenegro, Serbia and Turkey remains below 15% of the European average level. (See Section 4.4 for the full graph.)

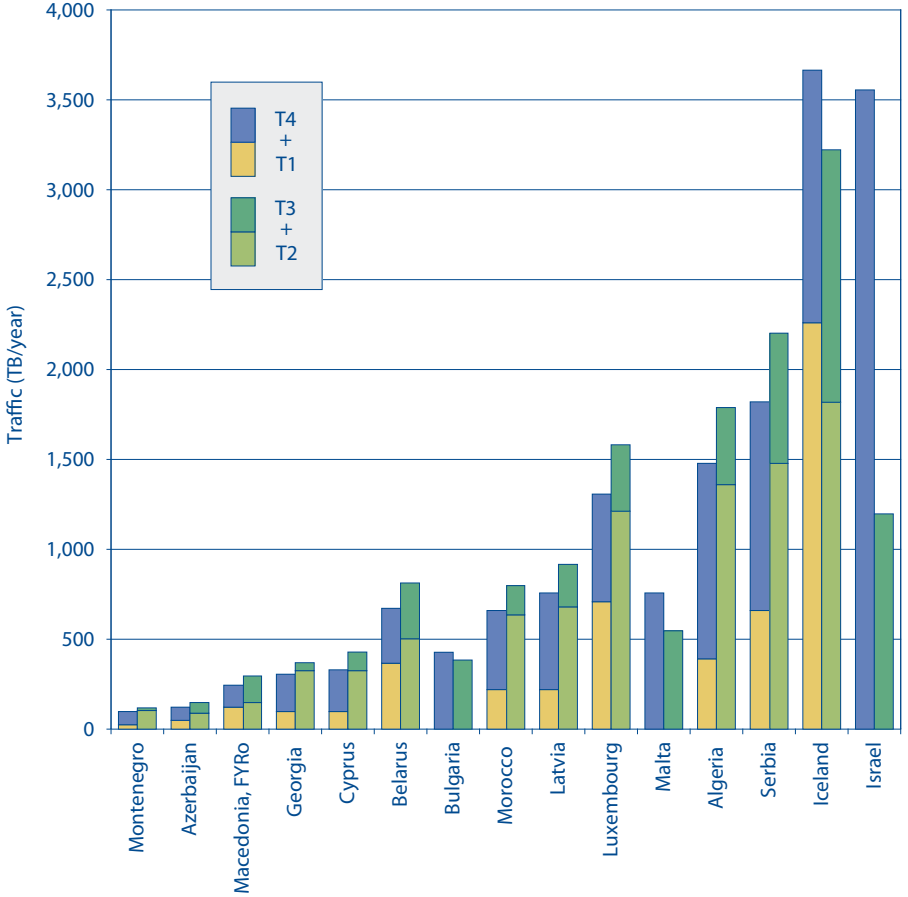
Average estimated congestion at campus level has consistently decreased for the GÉANT partner countries. However, it seems that recent investments in capacity increases at the external and backbone levels are causing some bottlenecks at the access network level. Congestion at the backbone and external connections levels seems to have been largely resolved for the time being.

Most NRENs think they will not be affected by a shortage in IPv4 address space, at least not in the immediate future, whereas a few are already affected. Most NRENs do not see a problem for their client institutions either, although the NRENs that see a problem for their institutions are greater in number than those that see a problem for themselves. In a few cases, the shortage is affecting the connection of new clients and/or the deployment of services. The great majority of NRENs provide some or all of their clients with both IPv4 and IPv6 connectivity. Clients using only IPv6 remain a rare exception.

At least 20 GÉANT partner NRENs now provide dedicated wavelengths (lambdas) to their customers. Per NREN, the number of lambdas provisioned in 2011 varies between zero and 141 (DFN of Germany). There is no consensus yet on how to document the traffic on these wavelengths. Counting the circuits may be an appropriate alternative method of measuring and documenting the evolution of lambda traffic. Within GÉANT, around 700 wavelength circuits are now in use for high-bandwidth, low-jitter transport (up from 200 last year).

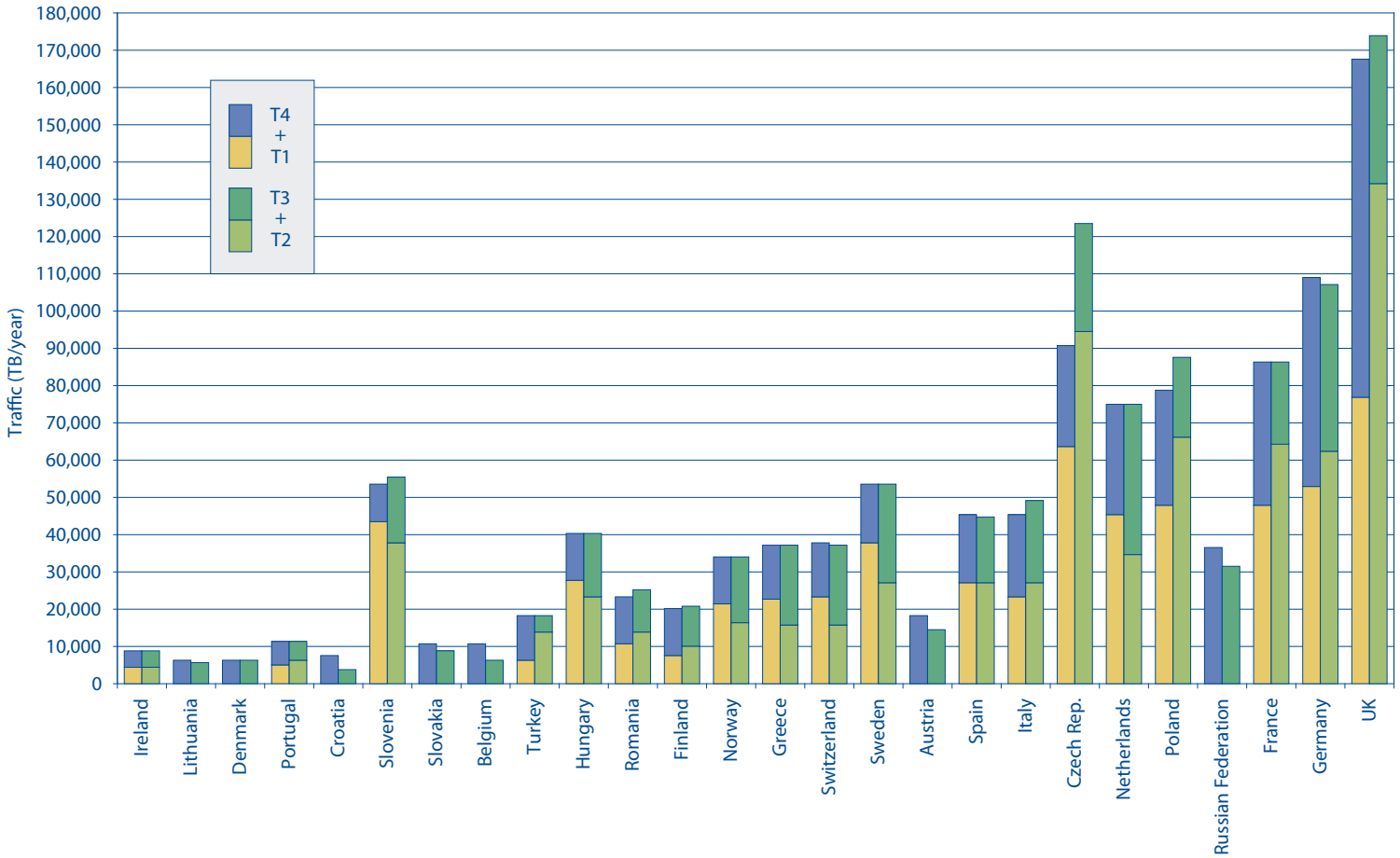
Graph 4.2.1 (right) represents the data submitted by those NRENs with T4 traffic exceeding 3500 terabytes per year, whereas Graph 4.2.2 represents the data submitted by NRENs with lower levels of T4 traffic. (In both graphs, the countries have been sorted on amounts of T4 traffic.) These graphs clearly show how the distribution of total traffic between the four categories (T1 to T4) differs from NREN to NREN. Note that not all respondent NRENs provided all four traffic values.

Graph 4.2.2 – 2010 traffic, T4 < 3500 TB



In most NRENs, the traffic sent into the NREN backbone (T1+T4) is equal or nearly equal to the traffic sent out of the backbone (T2+T3). That a few NRENs report a different situation may be due to traffic transiting agreements or because certain features (such as caching and multicasting) are sometimes regarded as services that belong in the backbone itself.

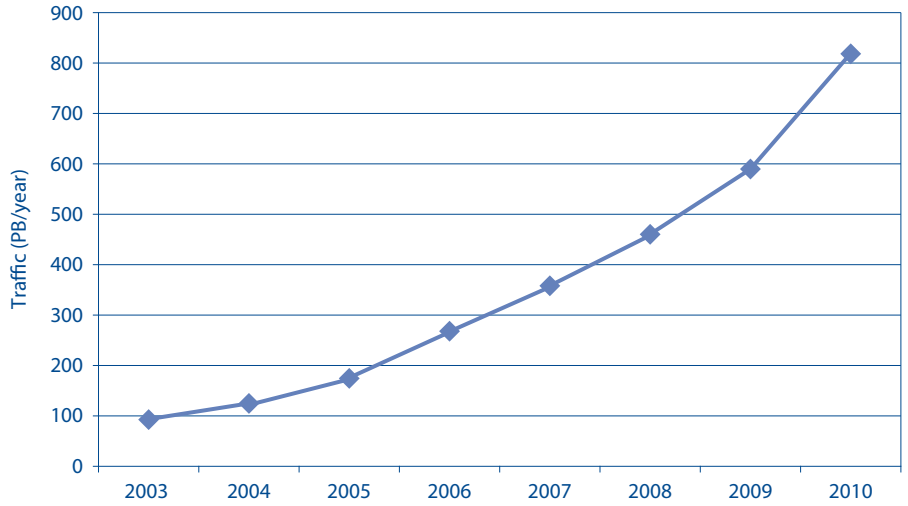
Graph 4.2.1 – 2010 traffic, T4 > 3500 TB



4.3 Traffic growth, 2004-2010

As in the 2010 edition of the *Compendium*, Graph 4.3.1 (below) shows T3+T4 values for a subset of 22 NRENs that have consistently submitted complete data.

Graph 4.3.1 – NREN annual traffic flows (T3+T4), 2003-2010, n = 22 NRENs

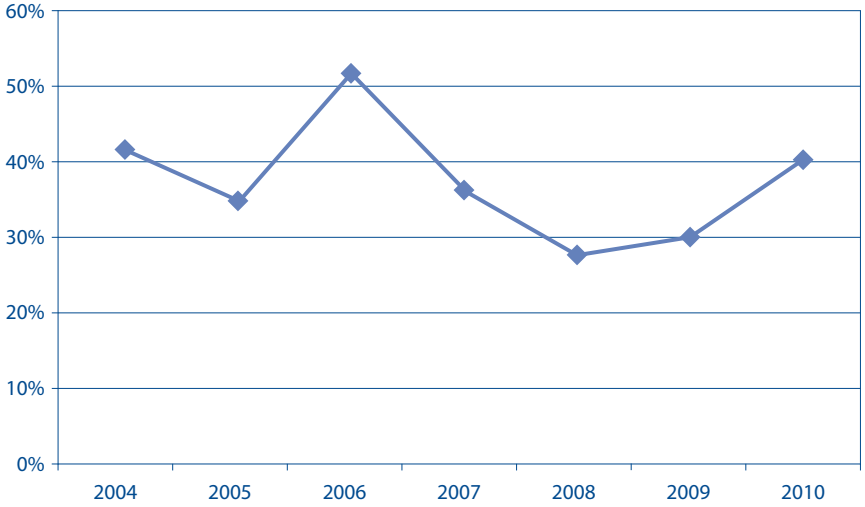


Clearly, over this seven-year period (2004-2010) traffic has continued to grow. The average annual rate is more than 37%. Graph 4.3.2 shows how the growth rate has varied over the same period.

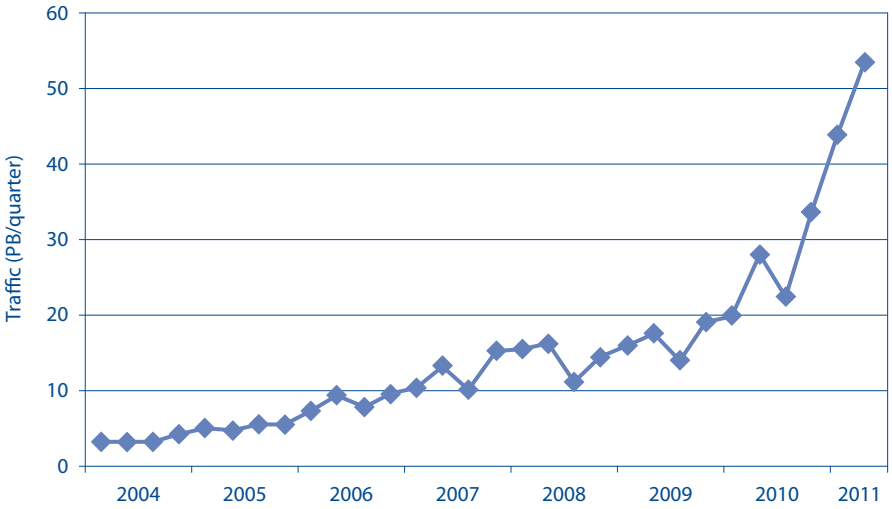
Using data from GÉANT service reports, the GÉANT IP traffic growth rate has been plotted in Graph 4.3.3 (right), which exhibits a trend similar to that evident in Graph 4.3.1 (above).

In mid-2005, sections of the underlying GÉANT infrastructure were migrated to dark fibre. Many NRENs started their transition to optical/dark fibre in the early years of the decade (2001-2010); for some NRENs, the transition is still proceeding. That such migration takes years to complete is probably the main, though not the sole, factor in the marked acceleration in growth since 2010.

Graph 4.3.2 – NREN traffic growth rate, 2004-2010 (in %, T3+T4)



Graph 4.3.3 – GÉANT IP traffic 2004-2011



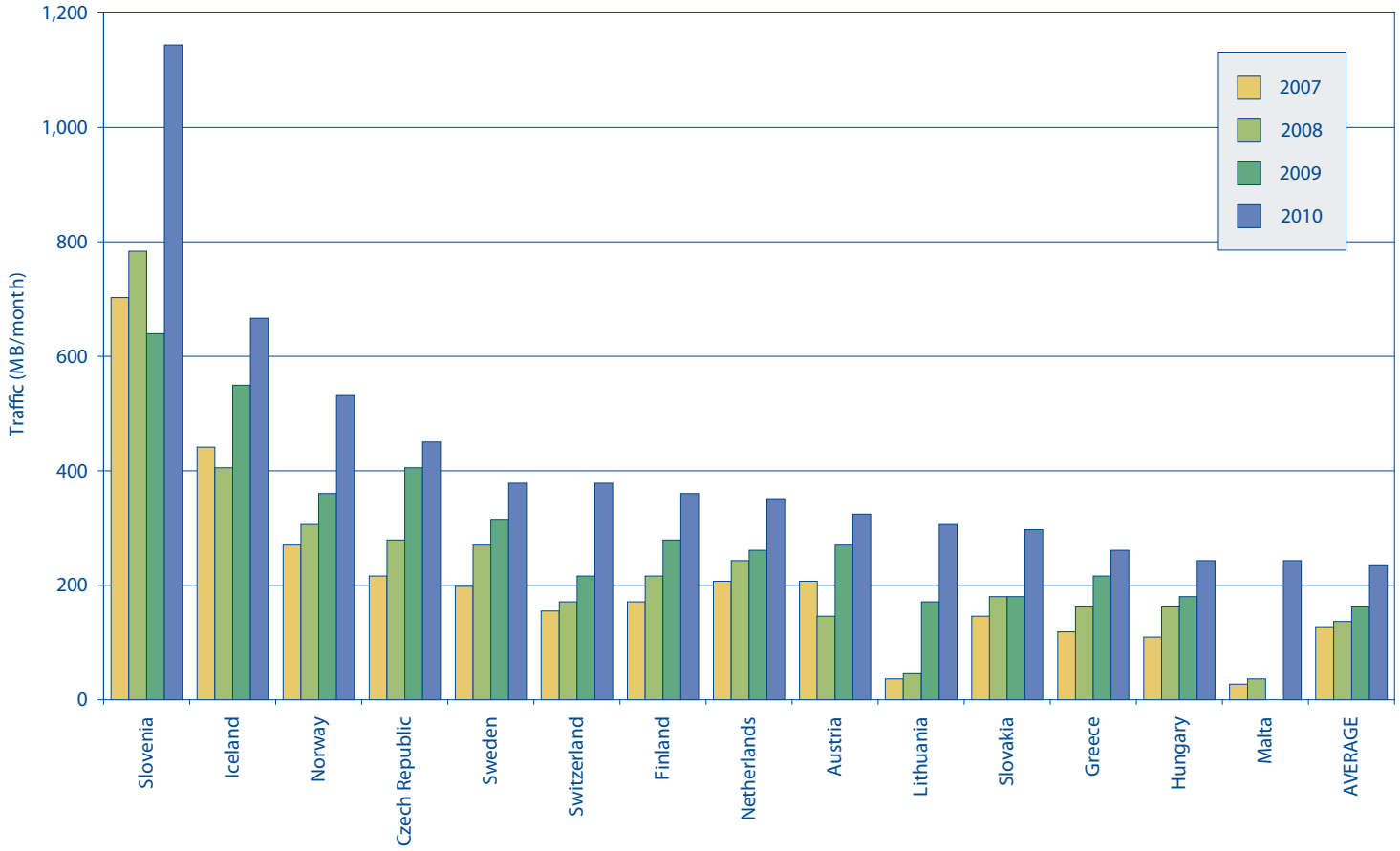
4.4 Traffic per inhabitant

It should be noted that these increases are not isolated events. Cisco predicts that mobile traffic will grow by 92% each year from 2010 to 2015 i.e. by a factor of 26 in those five years. For overall Internet traffic, the forecast growth rate is 32% per year.[1] Similarly, Morgan Stanley predict that the number of mobile Internet users will overtake the number of desktop users in 2014.[2]

It should be noted that the GÉANT network also includes P2P circuits. In the period 2007-2010, their number increased from 29 to 69. Unfortunately, we have no data on the traffic volumes in those circuits.

In 2009, we attempted to identify an indicator that would enable NRENs to be compared in terms of traffic. After considering several alternatives, the simplest indicator – traffic-per-inhabitant – was found to be the most reliable. Fortunately, for most countries, there is a strongly proportional relationship between the total national population and the size of the education and research community. Therefore, no other assumptions or data convolutions need to be made.

Graph 4.4.1 – Nominal external traffic (T3+T4) divided by total national population: greater than European average



[1] http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

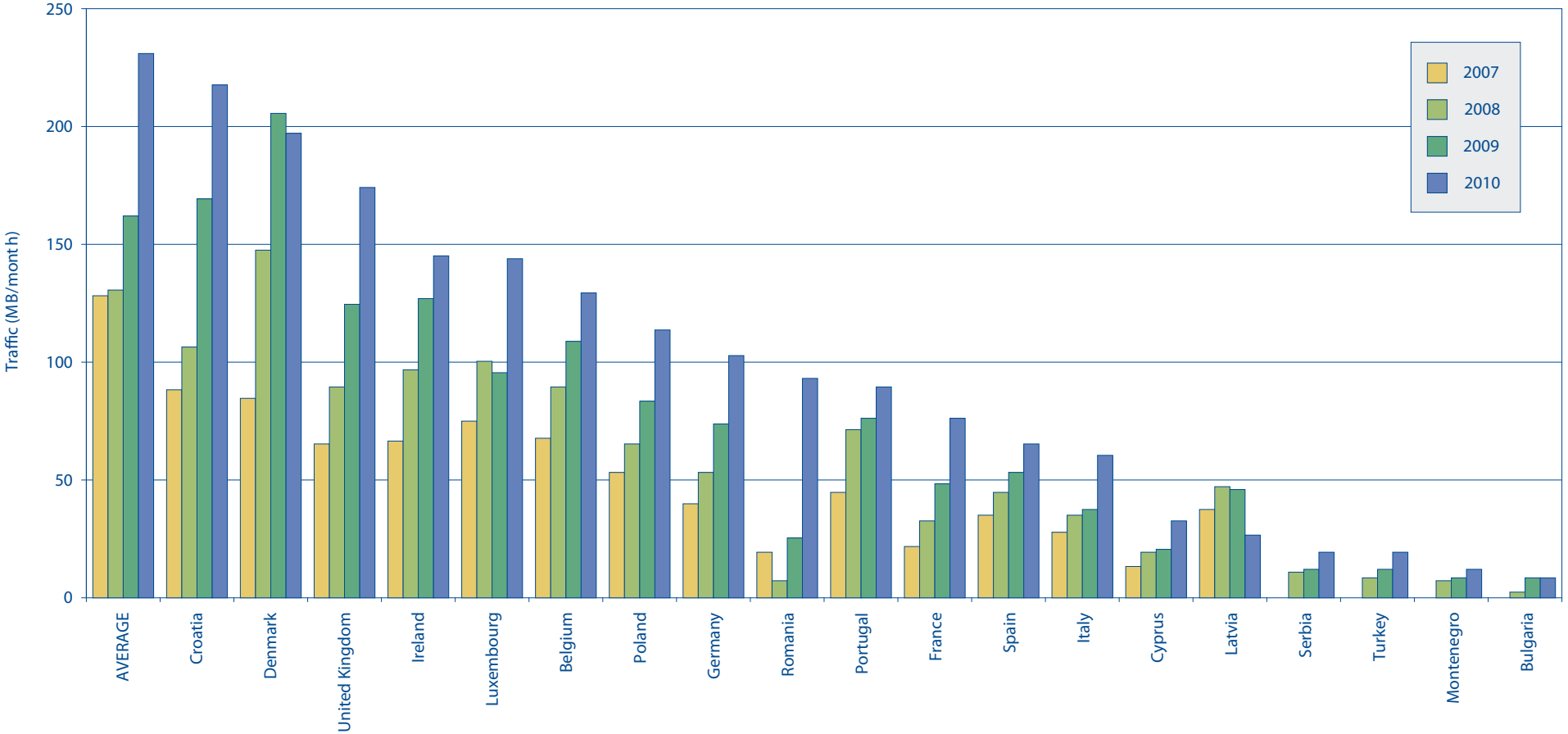
[2] http://www.morganstanley.com/institutional/techresearch/pdfs/Internet_Trends_041210.pdf

Graphs 4.4.1 and 4.4.2 show NREN annual T3+T4 traffic in 33 countries over the period 2007-2010, normalised according to the total national population in each corresponding year. Note that this figure should not be taken as an indicator of the network traffic generated by a typical NREN user.

The average traffic per inhabitant in these 33 countries has grown from 128 MB/month in 2007 to 231 MB/month in 2010, with an average annual growth rate of 21.7%.

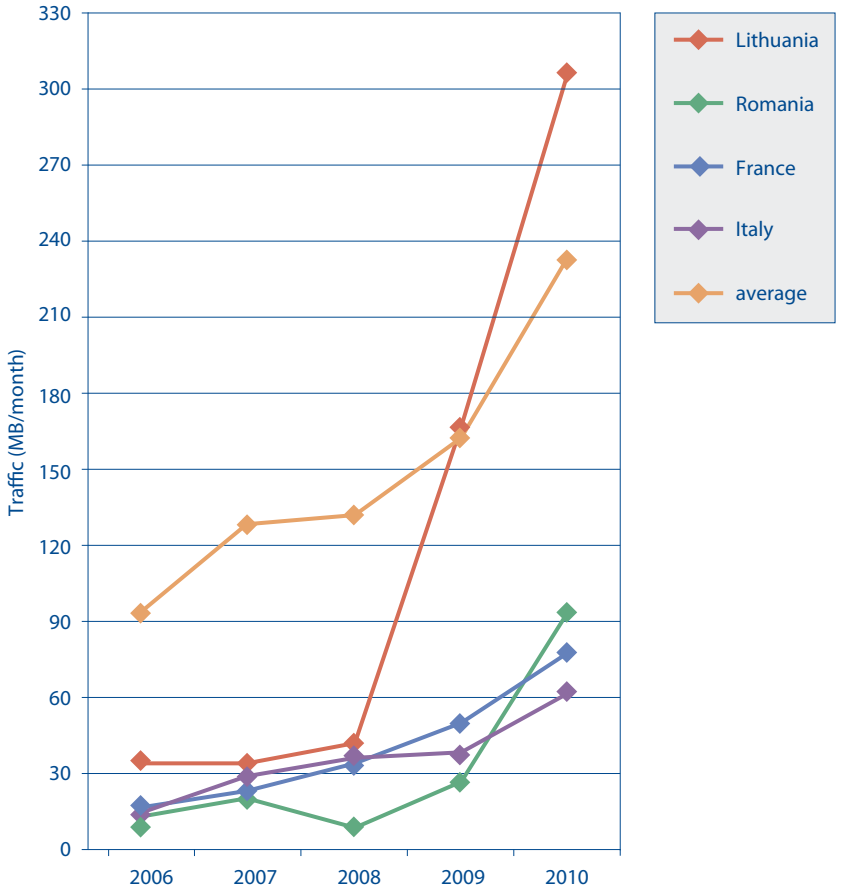
Slovenia, at the left, has had consistently high nominal traffic (per inhabitant) over the four-year period (2007-2010). In terms of population, Slovenia is a relatively small country, yet it has a relatively high proportion of traffic generated by primary and secondary schools: nearly 700 schools and just a few universities are connected to the ARNES backbone. Some of the schools are connected with gigabit capacities. Therefore, the proportion of the population that is connected by the NREN is relatively high, and Slovenia's external traffic is higher than that of the other European countries shown.

Graph 4.4.2 – Nominal external traffic (T3+T4) divided by total national population: lower than European average



Note that the vertical scale of Graph 4.4.2 is much larger than that of Graph 4.4.1. Clearly, there is still a substantial 'digital divide' in Europe: Bulgaria, Cyprus, Latvia, Montenegro, Serbia and Turkey show much lower values than the rest of Europe. Note the marked growth in Romania, which followed that country's changeover to a fibre network. Even more remarkable was the growth in Lithuania. Graph 4.4.3 shows countries with the highest growth in terms of traffic per inhabitant.

Graph 4.4.3 – Countries with the fastest growth in terms of traffic per inhabitant



Note that many countries with a relatively small number of inhabitants have relatively high traffic per inhabitant. Simply having an NREN itself generates a certain amount of traffic (including mirroring services, news groups and library databases), at least as soon as the NREN has attained a certain minimum level of development and connectivity. For larger countries, that 'base load' amount of traffic is not significant, though it does influence the statistics for smaller countries.

4.5 Congestion

The NRENs covered by this edition of the *Compendium* were asked to roughly estimate the percentage of institutions connected to their networks that experience none-to-little, some-to-moderate, or serious congestion at the various network levels.

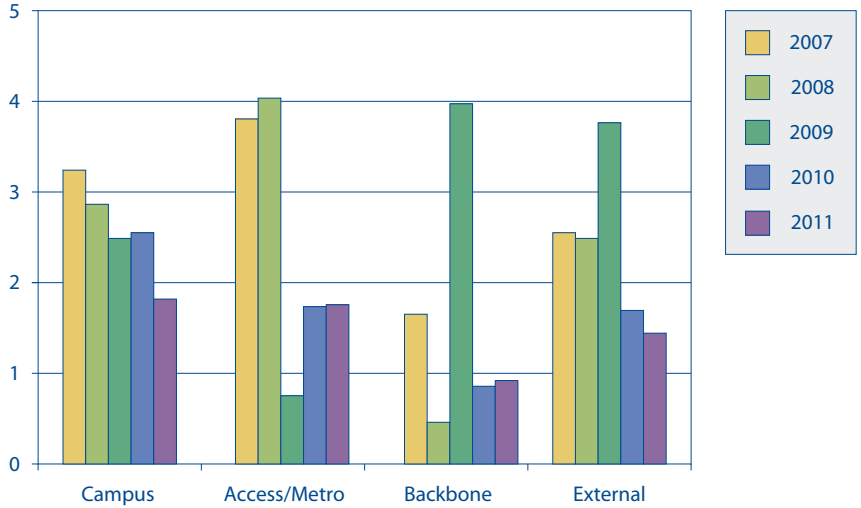
From the subjective levels reported by NRENs, a metric was derived for the level of congestion in each network element, using the following formula:[3]

congestion index = (0.05*little + 0.2*some + 0.5*serious) – 5

Note that the data for MANs and access networks were combined. Applied to all the submitted data on congestion, this formula provides a single uniform metric.

As shown by Graph 4.5.1 (below), for the GÉANT partner countries, the average estimated congestion at campus level has consistently decreased. However, it seems that recent investments in capacity increases at the external and backbone levels are causing some bottlenecks at the access network level. Congestion at the backbone and external connections levels seems to have been largely resolved for the time being.

Graph 4.5.1 – Congestion index, GÉANT partner countries, n=32



4.6 Transition to IPv6

There have been many reports about the impending shortage of IPv4 address space[4] and the need to change over to IPv6. As was shown in previous editions of the *Compendium*, most European NRENs have not yet started this transition, although they are ready for it when the need arises. The proportion of IPv6 traffic as compared to IPv4 traffic is very low and has not changed much over the last few years.

Even though IPv4 address space shortage may become a problem in the Internet community as a whole, the situation may be different for the NRENs. We therefore asked NRENs whether they or their client institutions see a threat in this area.

As Table 4.6.1 (right) clearly shows, most NRENs think they will not be affected by an address space shortage, at least not in the immediate future. However, a few are already affected. We also asked whether NRENs see a problem for their client institutions. Most NRENs see no problem in that area either, although the number of NRENs that do see a problem in this area is a little higher. In a few cases, the shortage is affecting the connection of new clients and/or the deployment of services.

A few NRENs do not yet provide IPv6 connectivity to any of their clients. However, the great majority of NRENs provide some of their clients with both IPv4 and IPv6 connectivity. Two NRENs (Belnet and SUNET) provide this to all of their clients. Clients using only IPv6 remain a rare exception. The GÉANT network itself has been carrying IPv6 traffic, along with IPv4, since 2000.

[3] This index was developed for the TERENA *Compendium* by Mike Norris of HEAnet. The index was modified in 2009 to set the minimum value at 0 rather than 5.

[4] See, for example, the IPv4 exhaustion counter at www.inetcore.com/project/ipv4ec/index_en.html

Legend for Tables 4.6.1 and 4.6.2 – Percentage of clients provided with v4 + v6

	No shortage foreseen
	Shortage foreseen in the medium term
	Shortage

	0%
	<40%
	40 - 60%
	>60%
	100%

Table 4.6.1 – IPv4 and IPv6, GÉANT partner countries

Country	IPv4 shortage?	IP4 shortage client institutions?	Comment	Affecting new clients?	% of clients using IPv4 only	% of clients provided with v4 + v6	% of clients using IPv6 only
GÉANT partner countries							
Austria		no		no	75	25	0
Belgium		no		no	0	100	0
Bulgaria		no		no	100	0	0
Croatia		no		no	28	72	0
Cyprus		no		no	100	0	0
Czech Republic		no		no	88	12	0
Denmark		no		no	20	80	0
Estonia		no		no	92	8	0
Finland	Not in the short term, but maybe in the future	yes	Some institutions have no problems with their address space, but for new customers or institutions currently using private addresses, that could be a problem. We are monitoring the situation.	no	77	23	0
France		no		yes	90	10	0
Germany	Possibly in the medium-term future	yes	Possibly in the medium-term future	no			
Greece	Since GRNET is deploying a cloud infrastructure aiming at the provision of virtual machines to students and researchers in Greece, in case public routable IPs will be required, IPv4 address space shortages may be faced.	no		no	75	25	0
Hungary		no		no	80	20	0
Iceland		no		no	98	2	0
Ireland		no		no	92	8	0
Israel		no		no	91	9	0
Italy		no		no	89	11	0

Table 4.6.1 – continued

Country	IPv4 shortage?	IP4 shortage client institutions?	Comment	Affecting new clients?	% of clients using IPv4 only	% of clients provided with v4 + v6	% of clients using IPv6 only
GÉANT partner countries							
Latvia		no		no	85	14	1
Lithuania		yes	It would not be the shortage of addresses, but the current bad practice design using multiple NATs that will eventually be replaced with the new version of IP	no	100	0	0
Luxembourg		no		no	95	5	0
Macedonia, FYRo		no		no	95	5	0
Montenegro	We have started using the last unused C class	yes	Institutions are already short of IPv4 space, and are forced to use NAT for parts of the network	yes	100	0	0
Netherlands		no		no	69	31	0
Norway		yes	Some member-institutions are running low on IPv4 addresses	no	85	15	0
Poland	We cannot assign address spaces as large as are requested	yes	Clients request address spaces larger than are available	no			
Portugal		no		no	35	65	0
Romania		yes		no	10	90	0
Slovakia		no		no	90	10	0
Slovenia		yes	We predict the first IPv4 address space shortage next year, especially if eduroam® continues to grow.	no	98	2	0
Spain		no		no	60	40	0
Sweden		no		no	0	100	0
Switzerland		yes	IPv4 address space shortage yes, but no problem. The sites just need to enable IPv6.	no	72	28	0
Turkey	We expect ULAKNET IPv4 address space to run out this year.	yes	The IPv4 address space allocated to ULAKNET is expected to be exhausted within this year.	no	85	15	0
United Kingdom		no		no	87	13	0

In the non-GÉANT countries, the situation is similar for the NRENs: they themselves are not affected by a possible shortage. However, the shortage does seem to be becoming increasingly acute for their client institutions, especially in the Asian region. In Asia, new IPv4 allocations are no longer possible. As a consequence, in Taiwan already 5% of the client institutions is provided with IPv6 connectivity only.

Table 4.6.2 - IPv4 and IPv6, other countries

Country	IPv4 shortage?	IP4 shortage client institutions?	Comment	Affecting new clients?	% of clients using IPv4 only	% of clients provided with v4 + v6	% of clients using IPv6 only
Other countries							
Algeria		no		no	100	0	0
Azerbaijan		no		no	100	0	0
Belarus		no		no	100	0	0
Bosnia/Herzegovina	Generally concerned	yes	Yes (we are generally concerned)	no	100	0	0
Georgia		no		no	100	0	0
Morocco		no		no	0	100	0
Russian Federation		no		no	95	5	0
Serbia	There are plans for connecting schools and we estimate that the whole network will need to use private IPv4 addresses with a carrier-grade NAT solution, because of the lack of IPv4 address space.	yes	Many client institutions do not have adequate IPv4 address allocation so they are forced to use NAT. This is a problem especially with large faculties and student dormitories that were recently connected.	no	92	8	0
Ukraine					100	0	0
Australia		yes		yes	67	33	0
Brazil		no		no	90	10	0
Canada		no		no	55	45	0
El Salvador		no		no	100	0	0
Korea		yes		no	50	50	0
Kyrgyzstan		no		no			
New Zealand		no		no			
Taiwan		yes	IPv4 addresses in the APNIC region have already been exhausted. New allocations can only get IPv6 addresses.	yes	80	15	5
Tajikistan		no		no	100	0	0
Turkmenistan		no		no	100	0	0
Uzbekistan		no		no	100		

4.7 Lambda traffic

Twenty of the GÉANT partner NRENs who responded to our questionnaire currently offer dedicated wavelengths (lambdas) to their customers, while one other is planning to introduce them. Only the Netherlands offers dynamic lambdas; outside of Europe, Australia also offers this facility. Most lambdas are used continuously. Measuring the traffic on these lambdas is inherently different to measuring traffic on the rest of the network. This is because this traffic is not always monitored by NRENs and is not necessarily transported as IP data packets.

The number of lambdas provisioned in 2010 ranges from zero to 141 (DFN of Germany) (last year, the highest number of lambdas reported by an NREN was 64, for CESNET of the Czech Republic). Provisioning time is between 24 hours (Belnet of Belgium) and one year. In part, these differences are due to differences in network architecture. In part, also, they may be due to differences in the way in which NRENs measure provisioning times. Typically, the lambda capacities are either 1 Gb/s or 10 Gb/s. Table 4.7.1 (below) shows that around 700 wavelength circuits are now in use, up from 200 last year.

The 2010 *Compendium* signalled the problems related to measuring lambda traffic. Many NRENs do not measure this type of traffic at all, whereas others are only able to measure the traffic via their own routers and/or IP-based traffic. An alternative method of measuring lambda take-up and traffic needs to be found. One alternative that has been suggested is to measure the number of circuits, rather than the traffic itself. Tables 4.7.1 and 4.7.2 at least provide an overview of the number of lambdas that has been provisioned as of 31 January 2011.

Table 4.7.1 – Lambda provisioning, GÉANT partner countries

Country	Lambda?	No. static	Charge?	Provisioning time	No. leaving country or NREN
GÉANT partner countries					
Austria	no				
Belgium	yes	63	yes	24 hours	0
Bulgaria	no				
Croatia	no				
Cyprus	no				
Czech Republic	yes	71	no, but planned	3 months	5
Denmark	yes	3 full 10Gs and 15 1G connections through shared lambdas	yes	3 - 12 months	1
Estonia	no				
Finland	yes	75	Yes. 1 Gb/s costs € 5,000/year and 10 Gb/s costs € 10,000/year, excluding possibly needed access fibre costs. Usually, we provide access via passive CWDM channels so we can use existing fibre infrastructure for the lightpaths.	1 Gb/s typically 1 week if fibre infrastructure exists; 10 Gb/s 8 - 12 weeks.	3
France	yes	125	no	3 months	8
Germany	yes	141	yes	average 4 months	Only CBF
Greece	yes	32λ WAN & 26λ MAN	no	2 days to provision a new λ on an existing link	None

Table 4.7.1 – continued

Country	Lambda?	No. static	Charge?	Provisioning time	No. leaving country or NREN
GÉANT partner countries					
Hungary	yes	6	no	two weeks	2
Iceland	no				
Ireland	yes	44 x 10GE	There is a charge in the form of one-off procurement costs. (A pair of transponders at the end points of the circuit.)	4 - 6 weeks	0 (not counting access circuits provided by JANET and GEANT)
Israel	no				
Italy	yes	29		60 - 90 days	3
Latvia	no				
Lithuania	yes				
Luxembourg	yes	17	no	4 month	1
Macedonia, FYRo	no				
Malta	no				
Montenegro	no				
Netherlands	yes	17	yes	3 weeks excluding new fibre orders.	17
Norway	yes	4	yes	4 to 8 weeks	0
Poland	yes	0	Yes	1 week	0
Portugal	yes	20	Historically, no costs were charged, but the official policy states that costs could be charged.	2 - 3 working days	1
Romania	no				
Slovakia	no				
Slovenia	yes	0	no		0
Spain	planned				
Sweden	yes	around 20	yes	Between 10 min and 12 weeks.	10
Switzerland	yes	3	yes	2 months	2
Turkey	no				
United Kingdom	yes	19	Yes, over 1Gb	40 working days	9

Table 4.7.2 – Lambda provisioning, other countries

Country	Lambda?	No. static	Charge?	Provisioning time	No. leaving country or NREN
Other countries					
Moldova	planned				
Russian Federation	yes	4		2 weeks	4
Australia	yes	71	yes	2 months	4
Korea	planned				

5 OTHER SERVICES

All NRENs provide a range of important services to their customers. The TERENA Task Force on Management of Service Portfolios is developing a typology of such services. The current draft has the following categorisation[1]:

1. Network & connectivity services (covered in Section 3 of this *Compendium*)
2. Security services (5.2)
3. Authentication and mobility services (5.3)
4. Housing, storage, hosting and content-delivery services (5.4)
5. Network collaboration tools & conferencing (5.5)
6. Network computing resources (5.6)
7. e-Learning / distance teaching & learning: e-research (5.7)
8. User interaction / knowledge dissemination (5.8)
9. NREN side activities/services (not NREN user-specific) (not covered separately in this *Compendium*)

5.1 Overview

Access to a service is becoming increasingly independent of the physical location of the user or service. As a result, there is a growing need for **security services**, identity federations and certification services; there are rapid developments in all these areas, which involve secure access by remote users.

Important new developments in the area of security include the adoption of structured formats for exchanging information about computer incidents and the use of network devices for addressing security threats. Many NRENs are also active in the related area of filtering out spam messages. In addition, twenty-one GÉANT partner NRENs are currently active in the area of DNS Security Extensions DNSSEC.

Almost all GÉANT partner NRENs currently provide an **Authentication and Authorisation Infrastructure** (AAI) or are planning to do this. In most, though not all, cases the web single sign-on federation is operated by the NREN.

Most of the GÉANT partner NRENs (and a few other NRENs as well) are planning to join the new **eduGAIN interfederation service**. Eleven of the GÉANT partner NRENs report some activity in the area of 2-factor authentication.

As of 31 December 2010, there were 77 144 outstanding **server certificates** that had been issued by GÉANT partner NRENs. Of those, 59% had been issued under the TERENA Certificate Service, 33% by the German DFN Public Key Infrastructure and 8% by others.

Many NRENs already provide, or are planning to provide, some kind of housing or **storage service**. The service that is currently offered by the largest number of NRENs is mirroring, mostly of open source software archives.

Just over one-third of the GÉANT partner NRENs currently offer a centrally-administered **VoIP (voice over IP) service**; this is not a significant change from last year's figure. A further 18% are planning to introduce such a service. Thirty-one of the GÉANT partner NRENs already provide or plan to offer a centrally managed video-conferencing service. The ITU-T H.323 communication protocol remains the most widely deployed technology, but the number of Session Initiation Protocol (SIP) enabled services has increased considerably to 25. Only two GÉANT partner NRENs (DFN of Germany and FCCN of Portugal) currently offer a mobile videoconferencing service for smartphones; ten others are planning to introduce this, a fact which indicates the growing importance of mobile devices, also for NRENs.

Nine GÉANT partner NRENs currently offer a platform of bundled **services for collaborative groups** of users; eight others are planning to introduce this. In most, though not all cases, these services are federated, allowing access to the services through a web-based authentication scheme.

Seventeen GÉANT partner NRENs currently offer a **multimedia content repository** and several others are planning to establish one. In 2010, a number of

[1] Developed by Koen Schelkens, BELNET.

NRENs have introduced user-initiated live streaming support. Increasing numbers of repositories have been made capable of standards-based metadata exchange. This allows a 'web' of NREN and other related repositories to be created. The number of objects stored in the repositories varies greatly from very few to thousands. Clearly, there is scope for considerable growth in this area.

The data show that in more than 50% of the GÉANT partner countries there is a **national computing service**. In 9% of the countries there are plans to set up such a service. In one-third of the countries, the national computing service is operated by the NREN.

Cloud services are not yet as common as national computing services. Seven of the GÉANT partner NRENs currently offer virtualisation services; fourteen others are planning to introduce them.

Increasing amounts of work are being done in the area of **e-learning**. Nine of the GÉANT partner NRENs currently provide an e-learning service. Five others are planning work in this area.

NRENs generally offer a range of **user-support services**, mostly in the form of training. Many NRENs also host national user-conferences and provide support to specific user-groups. The most popular broker service seems to be joint software licensing. This is an area in which NRENs will probably be able to achieve considerable savings for their customers and in which there is potential for expansion, especially given the current economic climate.

5.2 Security services

Security services are of growing importance to NRENs. In this year's *Compendium* survey, we have addressed a number of issues, which are summarized in Table 5.2.1 (below). For further information on how NRENs have recently been collaborating in the area of security, see for example the web pages of TF-CSIRT, at **www.terena.org/activities/tf-csirt**.

One question asked in the questionnaire was whether NRENs are using a structured format for the exchange of computer incident information. Such a format is useful in speeding up the exchange of information internationally and helps to avoid misunderstandings. Five of the GÉANT partner NRENs currently use such a format; five others are planning to introduce it. X-ARF is the most commonly used, but by no means the only, format.

Table 5.2.1 also provides information on whether network devices are used for addressing security threats and, if so, which types of devices.

In addition, Table 5.2.1 provides an overview of the anti-spam measures that many NRENs have taken.

Table 5.2.1 – Security services

Country	Structured format?	Network devices?	Anti-spam measures
GÉANT partner countries			
Austria	no	no	
Belgium	X-ARF , IODES	Routers: filtering IDP intrusion detection system (IDP): SNORT Netflow: identification and tracking of packet destination	Centralized anti-spam system based on Blacklisting
Bulgaria	no	no	
Croatia	no		DNSBLs, SPF record, SpamAssassin
Cyprus	no	no	
Czech Republic	Plan, format undecided	Plan, Firewalls, IDS, Netflow.	DNS SPF.

Table 5.2.1 – continued

Country	Structured format?	Network devices?	Anti-spam measures
GÉANT partner countries			
Denmark	no	yes	Anti-spam filter as a service
Estonia	no	routers, firewalls, IDPSs	DNSBLs, DNS SPF records, detection software
Finland	no	routers for rate limiting and filtering traffic	DNSBLs, DNS SPF records
France	xml	yes	anti-spam services implemented (DNS RBL + DNS SPF)
Germany	X-ARD, DAF	yes	DFN-wide spam filter
Greece	no	Simple access lists are applied to our core routers. Network security in our services is implemented by restricting access to the servers to specific IP domains and firewalls (based on iptables) in all hosts. No dedicated firewalls or similar cards are deployed.	DNSBLs, DNS SPF, DKIM
Hungary	no	No, remote blackhole triggering via BGP.	
Iceland	no	no	
Ireland	no	Cisco 5140 UTM (Fortinet), Juniper SRA. Both in use for content filtering for 4000 first and second level schools connectivity.	Spamhaus RBL, Trend Micro RBL (used to be MAPS RBL), DNS SPF records
Israel	no	Routers and firewalls.	Multiple actions
Italy	Plan, X-ARF	no	
Latvia	AIRT system - IODEF	Traffic filters on routers, stateless/statefull fw, IDPSs to protect certain domains.	Greylisting, DNSBLs
Lithuania	no	firewalls, IDS, honeypots	DNSBL, greylist
Luxembourg	no	firewalls	DNSBLs, DKIM

Table 5.2.1 – continued

Country	Structured format?	Network devices?	Anti-spam measures
GÉANT partner countries			
Macedonia, FYRo	no	yes	DNSBL, SPF, teergrubing, greylisting, Bayesian filtering
Malta			
Montenegro	no	ASA 5540	SPAM BL ACL's, SpamAssassin,
Netherlands	no	Yes	Running spamfilter service SURFmailfilter
Norway	no	router ACL, host-based firewalls	graylisting and content filtering
Poland	Planning to support ARF or IODEF, modified to take Polish legislation into account.	Firewalls: to protect crucial services and infrastructure. Routers: for border blackholing and also for load balancing in case of e.g. DDoS attacks.	Using RBLs to protect our internal users. Using firewalls to limit SMTP access via port 25 from some network segments. We try to react promptly to notifications from external spam traps that are sent to PIONIER-CERT's incident reporting address.
Portugal	no	IDS, routers	SPF
Romania	no	Fortigate and Cisco SCE are used at the border of the network.	DNSBL, Antivir
Slovakia	no	routers, firewalls	DNSBLs, DNS SPF records
Slovenia	Plan, X-ARF	Routers, Firewalls, IDS: for protecting connected institutions.	DNSBL, DKIM and other functionalities of SpamAssassin
Spain	X-ARF, IODEF	Routers implement firewall filters	DNSBL (with community whitelisting)
Sweden	no	yes	Canit Domain Pro
Switzerland	no	Router access lists, IDS	BATV, DNSBLs, DCC
Turkey	Plan, X-ARF	No, routers for collecting flows. Each node is operating its own firewall and/or IDS.	

Table 5.2.1 – continued

Country	Structured format?	Network devices?	Anti-spam measures
GÉANT partner countries			
United Kingdom	no	Cisco & Juniper routers. Purpose: filtering IP prefixes at borders; black-holing traffic with spoofed addresses; blocking traffic that is malicious or has a deleterious impact on services	Commercial anti-spamming products
Other countries			
Algeria	no	Plan: routers for backbone, firewalls for data centre, Traffic shaper	DNS SPF records, anti-spammer device
Azerbaijan	no	yes	DNSBLs, SPF records, anti-spam software (licensed)
Belarus	no	Firewalls, routers	
Bosnia/Herzegovina	no	Plan, routers-traffic filtering; Linux based IDS systems	DNS PTR, Mail Gateway
Georgia	plan	Routers, firewalls	DNSBLs
Moldova	Plan, VEDEF	Routers	SpamAssassin, RBL
Morocco	no	yes	DNS SPF
Russian Federation	X-ARF	firewalls	DNSBLs
Serbia	no	Routers with ACLs. Firewalls are planned for some specific type of institutions, i.e. schools and libraries	SpamAssassin
Ukraine	no		
Australia	no	router ACLs	
Brazil	Plan, IODEF	ARBOR Peakflow to identify and mitigate threats generatint unusual traffic flows, such as DDoS attacks, forms of malware, and policy violations.	Notification to the institution responsible for computers identified as spam source.
Canada	no	no	
El Salvador	no	No, Security Appliances	

Table 5.2.1 – continued

Country	Structured format?	Network devices?	Anti-spam measures
Other countries			
Kazakhstan	no	firewalls, routers for security	
Korea	no	Plan, Routers, TMS(Threat Management System)	
Kyrgyzstan	plan	Plan, Cisco ASA / firewall / IDS	DNSBLs, DNS SPF records
Malaysia	no	Firewall - PIX , routers - Flow analysis	alerted members on spam activities, shutting down access for non-compliant
New Zealand	no	no	
Taiwan	no	routers, firewalls, IDPs,	
Tajikistan	no	routers, Linux-routers	
Turkmenistan	no	Plan: routers and firewalls	
Uzbekistan	no	No, CISCO 7204	

DNSSEC is a new area included in this year's survey. DNS Security Extensions (DNSSEC) are a set of Internet Engineering Task Force (IETF) standards created to address vulnerabilities in the Domain Name System (DNS) and protect it from online threats. The purpose of DNSSEC is to increase the security of the Internet as a whole by addressing DNS security weaknesses. Essentially, DNSSEC adds authentication to DNS to make the system more secure.[2]

Table 5.2.2 (right) lists the NRENs that have DNSSEC-related activities and indicates their status. All the GÉANT partner NRENs responded to this question; 21 of them reported some level of activity. Several of the NRENs who reported no activity did mention that they were looking into the issue or planning some future activity. Several others reported that they did not consider this topic a priority and/or that there is no interest in their constituency.

Several activities are related to DNSSEC. Five NRENs mention that they operate a signed country-code top-level domain (ccTLD). Six operate a signed zone for

[2] Information courtesy of whatis.techtarget.com.

the NREN itself. Five operate signed zones for the constituency as a service; in addition, JANET (UK) operates the signed .ac.uk domain. Ten NRENs operate validating DNS resolvers for their constituencies.

Several NRENs have more than one activity; RESTENA of Luxembourg is working in all these areas. In the other countries that responded to this question there is far less interest, with only RNP of Brazil reporting that it is working in this area.

Table 5.2.2 - DNSSEC (Green highlight indicates that the NREN has activities related to DNSSEC)

Country	Explanation
GÉANT partner countries	
Austria	yes
Belgium	Signed zone for our NREN; Signed zones for our constituency as a service; DNS resolvers
Croatia	We operate the ccTLD and are preparing to deploy DNSSEC
Czech Republic	We are finishing implementation of signed zones for our constituency and DNS resolvers
Denmark	Signed zones for our constituency as a service; DNS resolvers
Estonia	Not important
Finland	Signed ccTLD
France	Minimum level of activity now; DNSSEC will become an important service to implement soon. We'll wait until more organizations have deployed it to be sure the related protocols are mature enough for a production service.
Germany	Signed zone for our NREN; DNS resolvers
Greece	DNS resolvers
Hungary	We have started the tests.
Iceland	Not needed
Ireland	We are involved in testing DNSSEC with the .ie TLD
Italy	We are studying the problem
Latvia	We are closely related to the ccTLD.
Lithuania	yes
Luxembourg	Signed ccTLD; signed zone for our NREN; signed zones for our constituency as a service; DNS resolvers
Malta	Planned
Montenegro	Not important
Netherlands	Signed zone for our NREN; signed zones for our constituency as a service; DNS resolvers
Norway	Not important; constituency not interested
Poland	Not important
Portugal	Signed ccTLD
Romania	Not important; constituency not interested
Slovakia	Not needed
Slovenia	DNS resolvers; signing is currently provided only in a test environment
Spain	Signed zone for our NREN; DNS resolvers
Sweden	yes
Switzerland	Signed ccTLD; signed zone for our NREN; DNS resolvers
Turkey	Planned in near future, but no manpower allocated to this topic at the moment.
United Kingdom	We operate a signed country-code, ac.uk, which has a scope that is wider than our NREN customer base
Other countries	
Azerbaijan	Not important
Bosnia/Herzegovina	Planned in distant future
Moldova	Constituency not interested
Morocco	Planned
Serbia	Currently we do not have enough manpower to dedicate to DNSSEC activities
Australia	Not important
Brazil	Signed zone for our NREN; signed zones constituency
Canada	Not needed
El Salvador	Not important
Kazakhstan	Not important
Korea	We plan to deploy DNSSEC in near future.

Table 5.2.2 - continued

Country	Explanation
Other countries	
Kyrgyzstan	yes
Malaysia	Constituency not interested
New Zealand	Not needed
Taiwan	Constituency not interested
Uzbekistan	Not important

5.3 Authentication and mobility services

Increasingly, the Internet is being used as a mechanism for delivering a range of services to specific user-groups. Thus, user access to services is becoming less dependent on the physical location either of the user or of the service. At the forefront of this development is the research and education community. Security is a key issue in this area: it is important to know who wants to access a particular service and who is entitled to do what. This means that authentication and mobility services go hand in hand. It also means that the development of these services can either constrain or stimulate the way other services are developed and delivered to users.

In Europe, a pioneering mobility service is eduroam®[3], which was established in 2003 under the TERENA umbrella and has developed into a secure roaming access service for the international research and education community. This service is currently offered by all 35 GÉANT partner NRENs and by NRENs in a growing number of countries in other regions and continents. However, this does not mean that eduroam is available in every institution or at all locations within a given institution. For further information on eduroam and its deployment, see **www.eduroam.org**.

[3] eduroam is a registered trademark of TERENA.

It should be noted that eduroam offers general Internet access but does not by itself permit access to any more specific services. In order to provide such access, identity services and authorisation are needed.

5.3.1 Identity federations[4]

An identity federation enables a user registered in the identity management system of his university to access services either provided by his university or by other institutions participating in the identity federation. Federated authentication across institutional boundaries originated in the NREN community. Like NRENs, federations have a variety of organisational forms (e.g. a project within a NREN, a consortium, a separate entity, collaboration with primary education, etc.). Normally, there is one federation for higher education and research in each country. NRENs either operate the research and education federation themselves or have close organizational ties with the federation in their country. These federations have implemented data protection in accordance with national and EU Data Protection Acts and actively work to preserve privacy while enabling sharing of user-related information.

Identity federations provide access to a variety of services, which may include: library resources; catalogue systems and document delivery; collaboration tools such as wikis; web-conferencing and mailing-list subscription services; and e-learning tools and web portals. In addition, there are services such as: video- and web-conferencing; MCU booking systems; streaming video portals; software licensing, and webshops for a range of academic services. Service providers can use federated access to identify and authorise a particular set of users; for example, students who may be entitled to special terms for travel, mobile phones, etc.

As reported in the *Compendium* since 2006, the number of identity federations has been growing constantly. In order to foster collaboration in this area, TERENA

[4] With contributions from Thomas Lenggenhager, SWITCH.

has facilitated the formation of REFEDS (Research and Education Federations), in which most federations collaborate. For further information, see **ww.refeds.org**.

With the growth of identity federations and federated services, the extra advantages of interfederating them has been recognised. The oldest operational interfederation activity is Kalmar2, which links the Nordic federations. The eduGAIN interfederation service started operating in 2011. For further information on eduGAIN, see **www.edugain.org**. Both eduroam and eduGAIN are supported by the EU through the GN3 project.

Table 5.3.1.1 (below) lists the current situation. Almost all GÉANT partner NRENs currently provide an Authentication and Authorisation Infrastructure (AAI) or are planning to do so. There are only two exceptions (RHnet of Iceland and SANET of Slovakia). In most, though not all, cases the web single sign-on federation is operated by the NREN.

Most of the GÉANT partner NRENs (and a few other NRENs as well) are planning to join the eduGAIN interfederation service, although a large minority (over one-third of the GÉANT partner NRENs) have no plans in this direction.

Table 5.3.1.1 - AAI

Country	AAI provided?	Federation	NREN-operated?	Interfederate?	Plans
GÉANT partner countries					
Austria	yes	yes	yes	no	
Belgium	yes	yes	yes	no	Access to REFEDS and eduGAIN are planned.
Bulgaria	plan	yes	yes	yes: eduGAIN	
Croatia	yes	yes	no	yes: eduGAIN	
Cyprus	plan	no	yes	no	
Czech Republic	yes	yes	yes	yes: eduGAIN	

Table 5.3.1.1 - continued

Country	AAI provided?	Federation	NREN-operated?	Interfederate?	Plans
GÉANT partner countries					
Denmark	yes	yes	no	yes: Kalmar	
Estonia	plan	no		no	eduGAIN, maybe also Kalmar.
Finland	yes	yes	yes	yes: Kalmar	
France	yes	yes	yes	no	Join the eduGAIN activity in GN3 project to develop the needed elements so our identity federation can comply with eduGAIN specs.
Germany	yes	yes	yes	yes: eduGAIN	
Greece	yes	yes	yes	yes: eduGAIN	
Hungary	yes	yes	yes	no	Interfederating from 2012 (eduGAIN).
Iceland	no	no		no	
Ireland	yes	yes	yes	yes: other	In 2011 we plan to interfederate - eduGAIN.
Israel	plan	no		no	
Italy	yes	yes	yes	no	Join eduGAIN
Latvia	plan	no		no	
Lithuania	plan	no		no	
Luxembourg	plan	no		no	
Macedonia, FYRo	plan	no		no	
Malta	yes	yes	yes	no	
Montenegro	yes	no		no	
Netherlands	yes	yes	yes	yes: eduGAIN	
Norway	yes	yes	yes	yes: Kalmar	

Table 5.3.1.1 - continued

Country	AAI provided?	Federation	NREN-operated?	Interfederate?	Plans
GÉANT partner countries					
Poland	plan	yes	yes	yes: eduGAIN	
Portugal	yes	yes	yes	no	eduGAIN integration planned for 2012
Romania	plan	no		no	Feasibility study is planned for 2012
Slovakia	no	no		no	
Slovenia	yes	yes	yes	no	We plan to connect to eduGAIN
Spain	yes	yes	yes	yes: eduGAIN	
Sweden	yes	yes	yes	yes: Kalmar	
Switzerland	yes	yes	yes	no	eduGAIN
Turkey	plan	no	no	no	As of 2011, we are in the pilot stage for eduGAIN service
United Kingdom	yes	yes	yes	no	
Other countries					
Algeria	plan	no		no	
Azerbaijan	plan	no		no	
Belarus	yes				
Bosnia/ Herzegovina	plan	no			
Georgia	no	no		no	Plan to join eduGAIN
Moldova	plan	no		no	
Morocco	plan	no		no	
Russian Federation	plan	no		no	
Serbia	yes	no		no	We are planning to start implementation in September 2011
Australia	no	yes	no	no	

Table 5.3.1.1 - continued

Country	AAI provided?	Federation	NREN-operated?	Interfederate?	Plans
Other countries					
Brazil	yes	yes	yes	yes: eduGAIN	
Canada	plan	no		no	
El Salvador	no	no		no	
Kazakhstan	yes	no		no	
Korea	plan	no		no	eduGAIN
Kyrgyzstan	plan	no		no	
Malaysia	plan	no		no	We are developing myIFAM to federate authentication using LDP for all in our NREN
New Zealand	no	no		no	
Taiwan	no	no		no	
Tajikistan	plan	no		no	
Turkmenistan	no	no		no	
Uzbekistan	yes	yes	yes	no	

5.3.2 Two-factor authentication

Two-factor authentication is a security process in which the user provides two means of identification, one of which is typically a physical token, such as a card, and the other of which is typically something memorized, such as a security code. A common example of two-factor authentication is a bank card: the card itself is the physical item and the personal identification number (PIN) is the data that goes with it.[5]

Eleven of the GÉANT partner NRENs report some activity in this area. Of those eleven, eight report that NREN staff use this form of authentication for accessing

[5] Source: searchsecurity.techtarget.com

some of the NREN services. Three NRENs offer 2-factor authentication services to their constituencies. Of the other countries, only Bosnia/Herzegovina reports doing some research in this area. The additional cost and complexity of deploying and supporting 2-factor authentication on a large scale still seems to be too high to justify replacing username/password credentials with related security problems.

Table 5.3.2.1 describes the types of service that are protected by 2-factor authentication. The last column shows other activities known to exist in the constituency that are not provided by the NREN. Only RedIRIS of Spain reported further activities related to 2-factor authentication. Their SIR federation integrates higher-level assurance authentication via connection to the STORK Pan-European Proxy Service. In addition, Austria and Portugal reported that in their user communities 2-factor authentication takes place via national ID cards; Germany is currently undertaking research on using the German ID card for such authentication.

Table 5.3.2.1 – 2-factor authentication

Country	Activities?	NREN staff use	Service to constituency	Protected services	Other activities
GÉANT partner countries					
Czech Republic	yes	yes	no	CA operations	PKI-based smart cards as employee IDs at some universities.
Denmark	yes	no	Password retrieval using national NemID system.		
Finland	yes	yes			
Germany	yes	yes	User Certificates at Smart Cards	Access to student portals	
Hungary	yes	yes	NIIF CA RA operators	NIIF CA RA	
Ireland	yes	yes		Network Operations monitoring, Documentation WIKI, Company Calendar web application, Company MIS systems (client, provider, supplier databases).	Online banking by HEAnet , Gmail used by certain clients.
Malta	yes	yes		Student Web Portal, University MIS Web portal (Finance, HR), IT Services Intranet (Request Tracker, IT Account Management, Document Management, Web drive, Wiki).	
Netherlands	yes	yes	no	Operation and maintenance portals, domain registration.	
Norway	yes	no	no		Access to core network components at the universities.
Spain	yes	no	no	Web services related to legally-binding processes, physical access.	Several institutions operate their own smartcard identification services.
Switzerland	yes	yes	no	VPN access	Institutional SSO

5.3.3 Certification Authorities

Digital certificates are issued by Certification Authorities (CAs) and are used to guarantee secure and reliable communication between servers, between users, or between a user and a server. For example, digital certificates can be used by:

- a user securely connecting to a web server and using a web browser;
- a user authenticating with a server using a digital certificate;
- two users exchanging encrypted emails using personal certificates.

The Grid community requires secure authentication for users to login to Grid resources; this requirement is met by using personal certificates. At present, server certificates are more widely used than client/personal certificates, as the former are required whenever a secure connection between servers, or between a client and server, is needed.

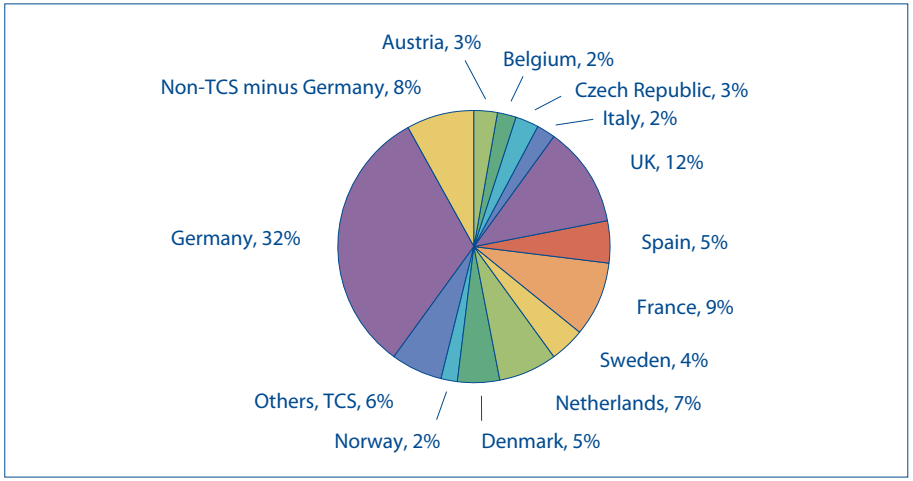
In order to support the user community (for example, in eScience) in deploying services in a secure manner, many NRENs run a Certification Authority. However, certificates issued by these authorities are not automatically trusted outside the NREN's own domain. Therefore, NRENs have requested that TERENA offer a Certificate Service. The first instance of this service, named the Server Certificate Service (SCS), was launched in 2006 and ended in January 2010. In 2009, a new provider was selected and more certificate types were added. The service was renamed as the TERENA Certificate Service (TCS). In January 2011, it supported 25 NRENs for server certificates, 20 for personal certificates and nine for code-signing certificates.

Many NRENs do not rely solely on the TCS for issuing certificates. Seventeen GÉANT partner NRENs operate certification authorities in addition to, or independent of, the TCS. By far the largest of these is in Germany. In fifteen cases, the CA is operated by the NREN itself; two NRENs (SWITCH of Switzerland and RESTENA of Luxembourg) use a commercial certification authority. Outside the GÉANT area, many NRENs also operate their own CA. These CAs usually issue server certificates; most issue personal certificates as well. In recent years, several initiatives have been set up to create a trust fabric in the academic community among academic CAs. One example is TACAR (**www.tacar.org**), a repository set up by TERENA for safe storage and distribution of root CA certificates. Another, more far-reaching, example is the set of Policy Management Authorities set up within the international Grid community. The European body is the EUGridPMA (**www.eugridpma.org**); worldwide collaboration takes place is through the International Grid Trust Federation (IGTF, **www.igtf.net**). Many NREN CAs are affiliated to the IGTF.

TCS Certificates are recognized by all major browsers and also accepted outside of the Grid community.

The 2008 edition of the *Compendium* reported that 16 000 server certificates had been issued by NRENs in the EU/EFTA countries. By the end of 2008, the figure had risen to 31 000, over half of which were issued by DFN in Germany (not a participant in the TCS).

Graph 5.3.3.1 – Server certificates, GÉANT area, 31 December 2010



In January 2010, the old service (SCS) was discontinued. The new service (TCS) was introduced gradually during 2009. Personal and eScience Personal Certificates, as well as code-signing certificates, were offered from 5 February 2010 onwards. As of 31 December 2010, there were 77 144 outstanding server certificates that had been issued by GÉANT partner NRENs. Of those, 59% had been issued under the TCS, 33% by the German DFN PKI and 8% by others.

Since 1 October 2010, the TCS has also been offering eScience Server Certificates, which are designed specifically for authenticating Grid hosts' and services' eScience Server certificates. These certificates are accredited by the EUGridPMA. Only 30 of these certificates were issued in 2010.

As of 31 December 2010, there were over 202 000 personal certificates outstanding in the GÉANT area, substantially more than the number of server certificates. The great majority of the former, around 200 000, were issued in Germany.

5.4 Housing, storage, hosting and content-delivery services

NREN users require access to a range of services to support their teaching, learning and research activities. One important category of services includes housing, storage, hosting and content delivery.

This year's survey focused on five areas in this category:

1. Is there a national storage service and, if so, who provides this service?
2. Is a commercial storage service provided by the NREN through a brokered deal?
3. Does the NREN host commercial-content servers or commercial content on the NREN network?
4. Are there video or multimedia content servers for use by NREN sites?
5. Is there mirroring of content from outside the NREN network?

For each of these areas, NRENs were asked to indicate whether they currently deploy the service, are planning to deploy it, or have no plan to do so. The results are summarised in Table 5.4.1 (below). Mirroring is the service that seems most popular in the GÉANT area. None of the NRENs covered by the survey currently provide a storage service from a commercial supplier, although three (Azerbaijan, Ireland and Netherlands) are planning such a service.

Table 5.4.1 – Storage and related services

	Grid storage	Peered commercial	Hosted commercial	Video service	Mirroring
GÉANT partner NRENs	26%	0%	45%	52%	65%

Seventeen GÉANT partner NRENs (52%) currently offer a video service and nine others are planning to introduce one. This is just one example of a range of real-time and synchronous collaboration services that are currently being investigated by NRENs.

Table 5.4.2 – Storage and related services

Country	Grid storage	Who provides it?	Hosted commercial	Video service
GÉANT partner countries				
Austria	no		yes	planned
Belgium	no		yes	no
Bulgaria	no		no	no
Croatia	planned		no	yes
Cyprus	planned		no	planned
Czech Republic	planned		yes	yes
Denmark	no		no	yes
Estonia	no		no	yes
Finland	yes	CSC — IT Center for Science Ltd.	yes	yes
France	no		yes	planned
Germany	no		no	planned

Table 5.4.2 – continued

Country	Grid storage	Who provides it?	Hosted commercial	Video service
GÉANT partner countries				
Greece	yes	The NREN	yes	planned
Hungary	yes	NIIF	no	yes
Iceland	no		yes	yes
Ireland	planned		yes	yes
Israel	no		no	yes
Italy	no		no	planned
Latvia	yes	IMCS UL	no	no
Lithuania	no		no	no
Luxembourg	planned		no	no
Macedonia, FYRo	yes	Distributed storage for GRID users.	no	yes
Montenegro	no		no	no
Netherlands	planned		no	no
Norway	yes	UNINETT Sigma AS	yes	planned
Poland	yes	The service is provided by a consortium of 10 members (HPC centres and MANs across Poland) coordinated by PSNC, under the project PLATON Popular Archive Services.	yes	yes
Portugal	planned		yes	yes
Romania	no		planned	planned
Slovakia	no		no	planned
Slovenia	no		no	yes
Spain	no		yes	yes
Sweden	yes	SNIC / SWESTORE	yes	yes
Switzerland	no		yes	yes
Turkey	yes	NREN	yes	yes
United Kingdom	planned			

Table 5.4.2 – continued

Country	Grid storage
Other countries	
Algeria	planned
Azerbaijan	planned
Bosnia/Herzegovina	planned
Georgia	no
Moldova	no
Morocco	no
Russian Federation	no
Serbia	no
Australia	planned
Brazil	planned
Canada	no
El Salvador	no
Kazakhstan	planned
Korea	planned
Kyrgyzstan	planned
Malaysia	planned
New Zealand	no
Taiwan	no
Tajikistan	no
Turkmenistan	no
Uzbekistan	yes

5.5 Network collaboration tools[6]

Over the past decade, NREN collaboration infrastructures and related services have become the cornerstone of European and worldwide collaboration among researchers and providers of higher education. Although technology has not changed profoundly during the last few years, the significantly increased quality and reduced price of collaboration hardware and software make network-based virtual meetings more appealing than ever before. In research and education, collaboration techniques are playing a key role in making project, research and administration work more effective, by virtually connecting remotely located personnel. Such remote collaboration helps to optimize how time is used, to reduce travel costs and to lower the environmental impacts of travelling.

Three pillars of the NREN collaboration infrastructure are:

1. Voice over IP (VoIP) to connect institutional IP telephony deployments or, to a lesser extent, individual end-users;
2. Video- and web-conferencing to provide a high-quality audio/video-based collaboration environment, often enhanced by other tools enabling joint work;
3. Multimedia content repositories for online presentation of materials recorded by higher education and research organisations to complement remote teaching/learning and science dissemination.

5.5.1 IP telephony

Just over one-third of the GÉANT partner NRENs currently offer a centrally-administered VoIP service. A further 18% are planning to introduce such a service.

Many other countries are also planning such a service; a few NRENs such as RNP of Brazil already offer it.

Most of the NRENs that offer a centrally managed VoIP service also provide an IP telephony interconnection facility to the institutions connected to their networks. Most, though not all, of those countries support the propagation of serviced E.164 numbers in ENUM or NRENUM.net.[7] Far fewer also provide a VoIP-to-PSTN[8] service, probably due to issues with accounting, billing and cost recovery. Generally, NRENs do not offer a VoIP service to individual users, probably because of security policies and difficulties in user authorisation. Table 5.5.1.1 (below) shows the most important data.

Table 5.5.1.1 – IP telephony

Country	Centrally managed	PSTN services	ENUM/ NRENUM.net	Individual users
GÉANT partner countries				
Austria	no	no	no	no
Belgium	planned	planned	planned	no
Bulgaria	planned	no	no	no
Croatia	yes	planned	yes	yes
Cyprus	planned	no	no	
Czech Republic	yes	no	yes	no
Denmark	no	no	no	no
Estonia	no	no	no	no
Finland	no	no	no	no
France	yes	planned	no	no
Germany	yes	planned	yes	no
Greece	yes	no	yes	yes
Hungary	yes	planned	yes	no
Iceland	no	no	no	no
Ireland	no	no	no	no
Israel	no	no	no	no
Italy	no	no	yes	no
Latvia	yes	planned	no	no
Lithuania	no	no	no	no
Luxembourg	planned	no	no	no
Macedonia, FYRo	planned	no	no	no
Montenegro	planned	no	no	no

[6] With contributions by András Kovacs, NIIF/HUNGARNET

[7] ENUM is a scheme for unifying the telephone number system of the Public Switched Telephone Network (PSTN) with the Internet addressing and identification namespaces. NRENUM.net is a pilot service run by TERENA for NRENs in countries that cannot yet participate in ENUM.

[8] Public Switched Telephone Network.

Table 5.5.1.1 – continued

Country	Centrally managed	PSTN services	ENUM/ NRENUM.net	Individual users
GÉANT partner countries				
Netherlands	no	no	no	no
Norway	yes	planned	planned	yes
Poland	yes	planned	yes	no
Portugal	yes	no	yes	no
Romania	yes	no	no	no
Slovakia	no	no	yes	no
Slovenia	no	no	no	no
Spain	no	no	no	no
Sweden	no	no	no	no
Switzerland	no	no	no	no
Turkey	yes	no	no	no
United Kingdom	no			
Other countries				
Algeria	planned	no	no	no
Azerbaijan	planned	no	no	no
Belarus	no			
Bosnia/Herzegovina	planned	no	no	no
Georgia	no	no	no	no
Moldova	planned	planned	no	no
Morocco	planned	no	no	no
Russian Federation	planned	planned		planned
Serbia	no	no	planned	no
Ukraine	no	no	no	no
Australia		no	yes	no
Brazil	yes	planned	no	no
Canada	no	no	no	no
El Salvador	planned	no	no	no
Kazakhstan	yes	planned	planned	planned

Table 5.5.1.1 – continued

Country	Centrally managed	PSTN services	ENUM/ NRENUM.net	Individual users
Other countries				
Korea	planned	no	no	planned
Kyrgyzstan	planned	planned	planned	no
Malaysia	planned	no	no	yes
New Zealand	no	no	no	no
Taiwan	yes	no	no	no
Tajikistan	planned	no	no	no
Turkmenistan	planned	no	no	no
Uzbekistan	no		no	no

5.5.2 Video-conferencing

As shown by Table 5.5.2.1 (right), thirty-one of the GÉANT partner NRENs provide or plan to offer a centrally managed video-conferencing service, which clearly indicates the strategic importance of video-conferencing. Such services are usually complemented by deployment of a multipoint conferencing unit (MCU) and availability of a central user-support team. The ITU-T H.323 communication protocol is still the most widely deployed technology. The more recent Session Initiation Protocol (SIP) is now gaining ground, with 22 GÉANT partner NRENs offering or planning to offer a SIP-enabled service. The H.323 protocol is still used in conjunction with the Global Dialling Scheme (GDS), a virtual numbering scheme that is supported by 19 NRENs within the GÉANT area; H.323 is also utilised by countries outside the GÉANT area.

Fifteen of the GÉANT partner NRENs offer high definition (HD) video-conferencing; five others are planning to introduce it. In 22 countries, recording and streaming of video-conferences is also available, or will be available in the near future. Fourteen GÉANT partners and seven other NRENs currently offer a centrally managed

webmeeting desktop service. The platform that is most commonly being used is Adobe Connect.

A mobile video-conferencing service for smartphones is currently being offered by two GÉANT partner NRENs (DFN of Germany and FCCN of Portugal); ten others are planning to introduce this, underlining the growing importance of mobile devices, also for NRENs.

Table 5.5.2.1 – Video-conferencing service deployment and planning

Country	Centrally managed	H.323 support	SIP support	GDS access support	High Definition	Recording and streaming	Webmeeting	Videoconferencing mobile
GÉANT partner countries								
Austria	planned							no
Belgium	yes	yes	yes	yes	planned	planned		no
Bulgaria	planned	planned	planned	no	no	no		no
Croatia	yes	yes	planned	yes	planned	yes	Adobe Connect	planned
Cyprus	planned							
Czech Republic	yes	yes	yes	yes	yes	yes	Adobe Connect	planned
Denmark	yes	yes	yes	yes	yes	planned	Adobe Connect	no
Estonia	no	yes	no	no	no	yes		no
Finland	planned	yes	yes	yes	yes	yes	Adobe Connect	no
France	planned							no
Germany	yes	yes	yes	yes	yes	yes	Adobe Connect	yes
Greece	yes	yes	no	yes	no	no		planned
Hungary	yes	yes	planned	yes	yes	yes	Vidyo with gateway	planned
Iceland	yes	yes	yes	yes	yes	no		no
Ireland	yes	yes	yes	yes	yes	yes		no
Israel	yes	planned	planned	no	yes	yes		no
Italy	yes	yes	yes	yes	planned	yes		planned
Latvia	no			no	no			no
Lithuania	no							no
Luxembourg	planned							planned

Table 5.5.2.1 – continued

Country	Centrally managed	H.323 support	SIP support	GDS access support	High Definition	Recording and streaming	Webmeeting	Videoconferencing mobile
GÉANT partner countries								
Macedonia, FYRo	yes	yes	yes	planned		yes		planned
Malta	yes	yes	yes		yes	planned		
Montenegro	planned	planned	planned	no	no	planned	Adobe Connect	no
Netherlands	yes	yes	yes	yes	yes	yes	Adobe Connect	no
Norway	yes	yes	yes	yes	yes	planned	Adobe Connect	no
Poland	yes	yes	yes	yes	yes	yes		no
Portugal	yes	yes	yes	yes	yes	yes	Radvision	yes
Romania	yes	yes	planned	planned	yes	planned		planned
Slovakia	planned							no
Slovenia	yes	yes	yes	yes	planned	yes	Adobe Connect	planned
Spain	planned	yes	no	yes	planned	planned		no
Sweden	no				no		Adobe Connect	no
Switzerland	yes	yes	no	yes	no	no	Adobe Connect	no
Turkey	planned							no
United Kingdom	yes	yes	yes	yes	yes	yes	EVO	planned
Other countries								
Algeria	yes	yes	yes	no	planned	planned		
Azerbaijan	yes	yes	yes	yes	yes	planned	other	no
Belarus	no							
Bosnia/Herzegovina	planned							
Georgia	no	yes	yes	no	no	no		no
Moldova	planned							no
Morocco	planned							no
Russian Federation	yes	yes	planned	planned	planned	yes		
Serbia	yes	yes	yes	yes	planned	planned		planned
Ukraine	yes	no	no	no	no	yes	Tixeo	no
Australia	yes	yes	yes	yes	yes	yes	vivu / vuroom, vidyo, Adobe Connect	planned

Table 5.5.2.1 – continued

Country	Centrally managed	H.323 support	SIP support	GDS access support	High Definition	Recording and streaming	Webmeeting	Videoconferencing mobile
Other countries								
Brazil	yes	yes	yes	planned	yes	yes	Adobe Connect	planned
Canada	no							no
El Salvador	no							no
Kazakhstan	yes	yes	yes	no	planned	yes		no
Korea	yes	planned	planned	no	yes	planned	Conference XP	no
Kyrgyzstan	yes	planned	planned		yes	planned		planned
Malaysia	yes	yes	yes	no	yes	yes		no
New Zealand	yes	yes	yes	yes	yes	yes	Scopia Desktop	no
Taiwan	no	yes	no	no	no	no		no
Tajikistan	no							no
Turkmenistan	no	no	no	no	no	no	Cisco	no
Uzbekistan	yes	planned	planned	planned	no	planned		no

5.5.3 Supporting Group Collaboration

Collaborative groups, sometimes referred to as virtual organisations, can serve individuals from more than one home institution, so the group is not bound to a single institution.

Nine GÉANT partner NRENs currently offer a platform of bundled services for collaborative groups of users; eight others are planning to introduce this. In most, though not all, cases these services are federated, allowing access to the services through a web-based authentication scheme.

The most common bundled services include mailing lists (mentioned 12 times), a wiki (11 times), a document store (9 times) and calendar/appointment planning (7 times).

Table 5.5.3.1 (below) provides further information:

Table 5.5.3.1 – Supporting Group Collaboration

Country	Platform of bundled services	Size of target groups	Services bundled	Services federated	Charging model
GÉANT partner countries					
Austria	planned	0-100	wiki, mailinglist	yes	free
Cyprus	planned		calendar, mailinglist		
Czech Republic	yes	0-20	wiki, document store, mailinglist, repositories - SVN, GIT. Redmine.	yes	free
Denmark	yes	100+	document store	yes	free
Estonia	yes	100+	wiki, document store, mailinglist		free

Table 5.5.3.1 – continued

Country	Platform of bundled services	Size of target groups	Services bundled	Services federated	Charging model
GÉANT partner countries					
France	planned	0-7	calendar, appointment planning, mailbox hosting	yes	
Greece	yes	0-20	wiki, document store, calendar, Redmine	yes	free
Hungary	yes	100+	mailinglist	no	free
Latvia	yes	0-20	wiki, mailinglist	no	free
Montenegro	yes	0-100	wiki, document store, calendar, appointment planning, mailinglist	no	free
Netherlands	yes	0-100	wiki, document store, calendar, appointment planning, mailinglist, other	yes	Fully recovered. Service providers bill the institutions.
Norway	planned	0-100	wiki, document store, calendar, appointment planning	yes	Partly subsidised. The tariffs have two parts: one fixed and one variable, depending on some measurement of size or usage.
Poland	yes	0-20	wiki, mailinglist	no	free
Slovenia	planned	0-100	calendar ,appointment planning, mailinglist	yes	free
Spain	planned	0-100	wiki, document store, calendar, appointment planning, mailinglist, Interaction with other NREN services (identity/ storage/instrument access/...)	yes	free
Sweden	planned				
Switzerland	planned	0-20	wiki, document store, mailinglist	yes	free

Table 5.5.3.1 – continued

Country	Platform of bundled services	Size of target groups	Services bundled	Services federated	Charging model
Other countries					
Azerbaijan	planned	0-100	wiki, document store, calendar, appointment planning, mailinglist	yes	free
Belarus	no				
Bosnia/ Herzegovina	planned	0-20	document store, calendar, appointment planning, mailinglist	yes	free
Brazil	yes	100+	wiki, document store, calendar, appointment planning, mailinglist, video- and webconference, 2 to 3 every day	yes	Fully financed by the Ministries of Education, Science & Technology, and the Ministry of Health.
Canada	yes	0-20	wiki	yes	free
Kazakhstan	yes	0-20	document store	no	free
Korea	yes	0-7	wiki, mailinglist	no	
Kyrgyzstan	planned	100+	wiki, document store, calendar, appointment planning, Moodle	yes	free
Malaysia	yes	0-100	wiki, document store, mailinglist	no	free
Moldova	planned	0-20	wiki, document store, calendar, appointment planning, mailinglist	no	
Taiwan	yes	0-20	wiki, mailinglist	no	free

5.5.4 Multimedia repositories and streaming

As in the questionnaire for last year's *Compendium* (2010), this year we asked about the use of multimedia repositories (audio/video archives) and streaming services offered by NRENs. This area is becoming increasingly important in the distribution of audio/video materials created by the research and higher-education user community, and NRENs seem to be well positioned to offer such a national service. As shown by Table 5.5.4.1 (below), 17 GÉANT partner NRENs currently offer a multimedia content repository and nine others are planning to establish one. Fourteen NRENs also feature or are planning to introduce video-sharing functionality, which enables the end users to publish and manage the content they have created. NRENs as repository providers follow a federative approach, as many of them have implemented metadata exchange capabilities in order to allow propagation of audio/video metadata to other content aggregators. The most popular technology is OAI-PMH (Open Access Initiative – Protocol for Metadata Harvest) and RSS. In 2010, a number of NRENs introduced user-initiated live streaming support.

The number of objects stored in the repositories varies greatly, from a hundred or so to thousands of objects in the Czech Republic and 20 000 object references in Spain. Clearly, there is scope for considerable growth in this area.

Interestingly, several NRENs have started to use the .tv domain for their multimedia services.

Table 5.5.4.1 – Multimedia repository services

Country	Multimedia repository	URL	Video sharing	Metadata exchange, technology used	Live streaming	Number of objects stored
GÉANT partner countries						
Croatia	yes	mod.carnet.hr	yes	oai-pmh	yes	>1000
Cyprus	planned					
Czech Republic	yes	videoserver.cesnet.cz	no	planned	yes	Thousands
Denmark	yes	www.edumedia.dk	yes	open-api	no	1747
Estonia	yes	www.koolielu.ee	yes	oai-pmh	yes	Currently very few
Finland	yes	tv.funet.fi/medar	planned	oai-pmh, rss, open-api	planned	Approx. 1500
France	yes	www.renater.fr/Video	no	no		
Germany	planned					
Greece	yes	vod.grnet.gr	planned	planned	yes	
Hungary	yes	www.videotorium.hu	yes	oai-pmh	yes	3000
Ireland	yes	media.heanet.ie	yes	no	yes	4965
Israel	yes	maor.iucc.ac.il/english.php	planned	oai-pmh	yes	300 data + 1500 meta
Italy	yes	www.garr.tv	planned	rss	yes	150 videos
Macedonia, FYRo	planned					
Montenegro	planned					
Netherlands	yes	www.surfmedia.nl	yes	rss,open-api	yes	

Table 5.5.4.1 – continued

Country	Multimedia repository	URL	Video sharing	Metadata exchange, technology used	Live streaming	Number of objects stored
GÉANT partner countries						
Norway	planned				planned	
Poland	yes	fbc.pionier.net.pl	planned	oai-pmh	yes	
Portugal	yes	www.zappiens.pt	yes	oai-pmh	yes	1750
Romania	planned					
Slovakia	planned					
Slovenia	planned	www.arnes.si/storitve/multimedijske-storitve/videoarhiv.html	planned	planned	yes	
Spain	yes	arca.rediris.es	no	rss	no	20 000 object references
Sweden	planned					
Switzerland	yes	cast.switch.ch	yes	oai-pmh	no	
Turkey	yes		no	no	yes	
Other countries						
Algeria	planned					
Azerbaijan	planned		planned		no	
Bosnia/Herzegovina	yes		yes	rss		
Moldova	planned					
Morocco	planned					
Russian Federation	planned	www.fcior.edu.ru				
Serbia	yes	media.amres.ac.rs	yes	no	yes	136
Australia	planned					
Brazil	yes	video.rnp.br	yes	oai-pmh, rss	yes	900
Kazakhstan	planned					
Kyrgyzstan	planned					
Malaysia	planned					

5.6 Network computing resources

5.6.1 National computing services

National computing services have become an important area for NRENs. Projects and organisations such as the European Grid Infrastructure (**www.egi.eu**) aim to introduce a production Grid service for scientific research purposes, using distributed computing services. In many cases, the NRENs provide the networking infrastructure for such services and are expanding into the offering of additional services to the Grid community. In almost all cases, these services are international in geographical scope.

The data gathered show that in more than 50% of the GÉANT partner countries there is a national computing service. In 9% of the countries there are plans to set up such a service. In 32% of the countries, the national computing service is operated by the NREN.

Graph 5.6.1.1 – National Computing Services, GÉANT partner countries

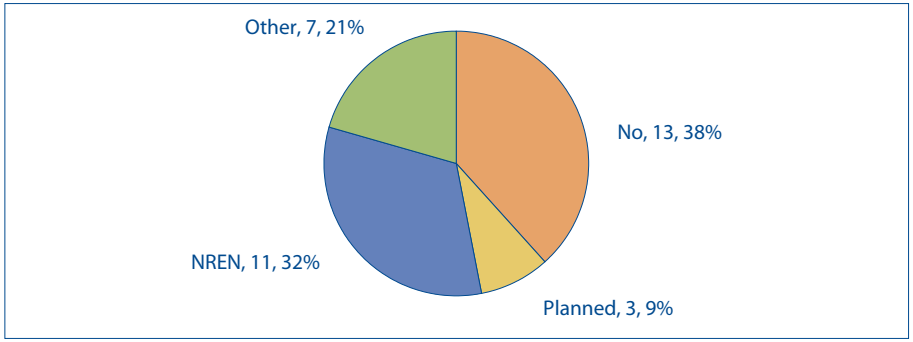


Table 5.6.1.2 (right) shows which organisation provides the national computing service in the various countries. It also shows where dedicated point-to-point IP circuits are provided and what storage type is available. For further information, see the NREN entries at **www.terena.org/compendium**.

It should be noted that many NRENs also connect other kinds of e-Science resources, such as telescopes. GRNET, for example, connects the institute that hosts a deep-sea high energy neutrino telescope.

Table 5.6.1.2 – National computing services

Country	National computing service?	Provided by	Point-to-point?	Storage type?
GÉANT partner countries				
Austria	no			
Belgium	yes	NREN	no	no
Bulgaria	no	planned	planned, distributed	
Croatia	yes	SRCE	planned	planned
Cyprus	no			
Czech Republic	yes	NREN	planned	planned, distributed
Denmark	yes	www.dcsc.dk		
Estonia	yes	NREN	planned	deployed, distributed
Finland	yes	CSC — IT Center for Science Ltd. deployed	deployed, centralised	
France	yes	set of academic orgs		
Germany	no			
Greece	yes	NREN	planned	deployed, centralised
Hungary	yes	NREN	deployed	deployed, distributed
Iceland	no			
Ireland	yes	ICHEC - Irish Centre for High-End Computing		
Israel	no			
Italy	no			
Latvia	yes	IMCS UL	no	deployed, centralised

Table 5.6.1.2 – continued

Country	National computing service?	Provided by	Point-to-point?	Storage type?
GÉANT partner countries				
Lithuania	no			
Luxembourg	yes	NREN	no	planned, centralised
Macedonia, FYRo	yes	Grid		
Montenegro	planned	planned	planned	
Netherlands	no			
Norway	yes	NREN	deployed	deployed, distributed
Poland	yes	NREN	deployed	deployed, distributed
Portugal	no	planned		
Romania	no			
Slovakia	planned			
Slovenia	yes	NREN	deployed	deployed, centralised
Spain	no			
Sweden	yes	SNIC		
Switzerland	yes	CSCS		
Turkey	yes	NREN	planned	deployed, distributed
United Kingdom	no			
Other countries				
Algeria	yes	NREN		deployed, distributed
Azerbaijan	planned			planned, centralised
Belarus	planned			
Bosnia/ Herzegovina	no			
Georgia	yes	NREN	no	deployed, centralised

Table 5.6.1.2 – continued

Country	National computing service?	Provided by	Point-to-point?	Storage type?
Other countries				
Moldova	planned	NREN	no	no
Morocco	no			
Russian Federation	planned			
Serbia	planned			
Australia	yes	nf.nci.org.au	planned	
Brazil	yes	The national computing service already deployed is called SINAPAD (Brazil's National Infrastructure for High-Performance Computing and Mass Storage), provided by the National Laboratory for Scientific Computing (LNCC) www.lncc.br/sinapad.	deployed	planned, centralised
Canada	no			
El Salvador	no			
Kazakhstan	yes	NREN	planned	planned, centralised
Korea	yes	Supercomputing Center in KISTI	deployed	deployed, distributed
Kyrgyzstan	planned			
Malaysia	yes	National agency - MIMOS and other universities.		
New Zealand	planned			
Taiwan	planned			
Tajikistan	no			
Turkmenistan	no	no	no	
Ukrain	planned			
Uzbekistan	no			

5.6.2 Cloud services

Cloud services are not yet as common as national computing services. Seven of the GÉANT partner NRENs currently offer virtualisation services; fourteen others are planning to introduce them. In most cases, these services have been developed and are hosted by the NREN. Only SURFnet of the Netherlands offers services provided by Google, Microsoft and Rackspace. Outside this area, many NRENs are planning to introduce such services; CANARIE of Canada already offers them.

The number of CPU cores offered by the service is limited in most cases. Notable exceptions are PIONIER of Poland with 1528 cores and GRNET of Greece, which is planning to increase from 512 cores to more than 5000 by the end of 2012.

Typically, the smaller services are housed in one facility, whereas the larger ones are distributed. Table 5.6.2.1 (below) details the various ways in which users can manage the resources allocated to them. They are usually allocated on a first-come, first-served basis. In most cases, the NRENs offer permanent storage of data outside of the virtual machines.

Table 5.6.2.1 (below) also shows the storage volume and location, user management tools, the storage interface, which resources are available via an API, the management tools developed or used by the NREN, and information about the NREN storage backends.

Table 5.6.2.1 – Cloud service details

Country	Storage volume, location	How users manage their allocated resources	Distributed computational frameworks (e.g. Hadoop)?	Storage interface	Resources available via API? Which?	Management tools?	Cloud storage backend
GÉANT partner countries							
Croatia	20 TB, single facility	They cannot directly manage resources. Instead, they have to ask us to implement changes.	no		no		
Estonia	12 TB, single facility	Via web interfaces	yes	Network File System	no		
Greece	0.5 PB / 2.5 PB (Q4 2011), distributed	Web interface, API	no	Openstack object storage	Rackspace/ Openstack API	code.grnet.gr/ (Q4 2011)	NFS, DRBD, RADOS
Hungary	500 TB, distributed	By using OpenNebula	no	iSCSI	no	At OpenNebula site as contributed modules.	iSCSI
Malta	Distributed						
Poland	Disk volumes (2 PB) and tapes (12,5 PB). 1 PB of disk + 12,5 PB of tapes work in 5 HSM systems. Distributed	Virtualization platform + software developed in-house	yes	sFTP, WebDAV, GridFTP access to a remote virtual filesystem with transparent data and metadata replication	no	Tools are not yet available as they are in beta stage; requests for tools will be evaluated on an individual basis.	
Turkey	250 TB, single facility	The resources are allocated centrally by us.	yes		no	internal	glusterfs,san,nas
Other countries							
Canada	48, distributed	Through OpenStack interface	no	OpenStack and EC2 API	EC2 API	Euca2ools	

5.7 e-Learning

As table 5.7.1 (below) shows, nine of the GÉANT partner NRENs currently provide an e-learning service. Five others are planning work on this. In many cases, further information can be found on the NREN websites. Several NRENs outside the GÉANT area are also active in this domain.

Table 5.7.1 – e-Learning services of NRENs

Country	Service provided?	URL	Standards
GÉANT partner countries			
Croatia	yes	www.carnet.hr/education/e-learning_academy www.carnet.hr/education/moodle_in_carnet www.carnet.hr/education/e_courses_for_teaching www.carnet.hr/education/nikola_tesla_national_distance_learning_portal	SCORM standards are followed in developing learning materials. Also W3C accessibility guidelines are followed in E-learning academy materials.
Estonia	yes	www.koolielu.ee viko.edu.ee	
Germany	yes		Via webconferencing
Israel	yes	meital.iucc.ac.il/meital/English/English.htm	
Italy	yes	learning.garr.it/learning	
Macedonia	planned		
Malta	yes	www.um.edu.mt/vle	
Montenegro	yes	moodle.ac.me	
Norway	planned	We are building an infrastructure to support e-Learning in our eCampus programme.	TBD
Poland	planned		
Portugal	yes	educast.fccn.pt	
Slovenia	yes	We provide hoster LMS (Moodle).	
Turkey	planned		
United Kingdom	planned		

Table 5.7.1 – continued

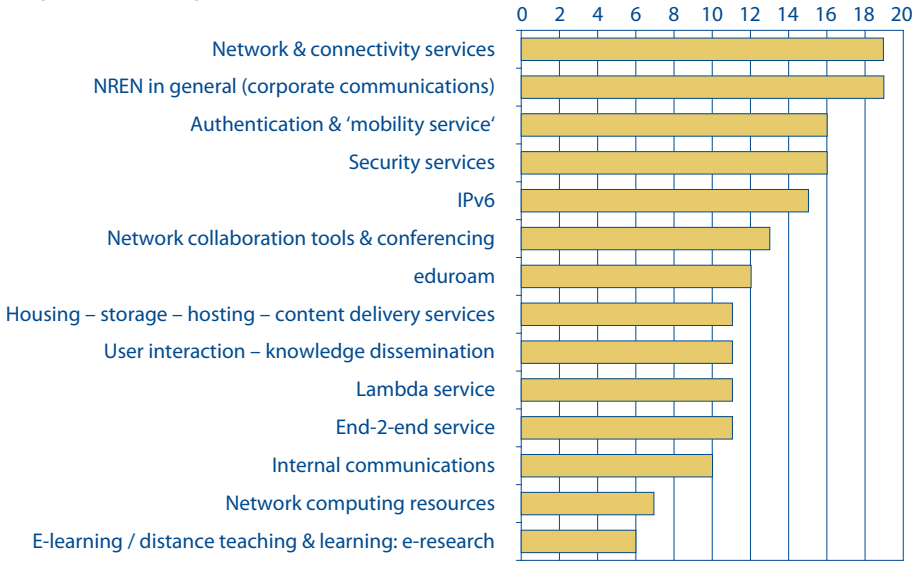
Country	Service provided?	URL	Standards
Other countries			
Azerbaijan	planned		
Georgia	yes	elearning.grena.ge	
Moldova	planned	www.renam.md/moodle	
Russian Federation	planned		
Serbia	yes	elearning.amres.ac.rs	
Kazakhstan	yes	www.rmeb.kz	KazRENA runs the National Inter-University e-Library
Kyrgyzstan	planned		
Turkmenistan	planned		
Uzbekistan	yes	www.uzscinet.uz	CISCO Academy

5.8 User interaction / knowledge dissemination

As in previous years, almost all NRENs provide some form of training courses to their users, and most organise national user conferences. For further information about such activities and the associated resources that NRENs make available to their users, see the separate TF-CPR *Compendium*: **www.terena.org/activities/tf-cpr/compendium**.

Some of the information gathered in that document is also of interest for the purposes of this *Compendium*; in particular, which topics organisations indicated as being (very) important for Communications/PR efforts in 2011/2012. This provides an indication of where the NRENs' priorities lie.

Graph 5.8.1 – NREN priorities in communications/PR

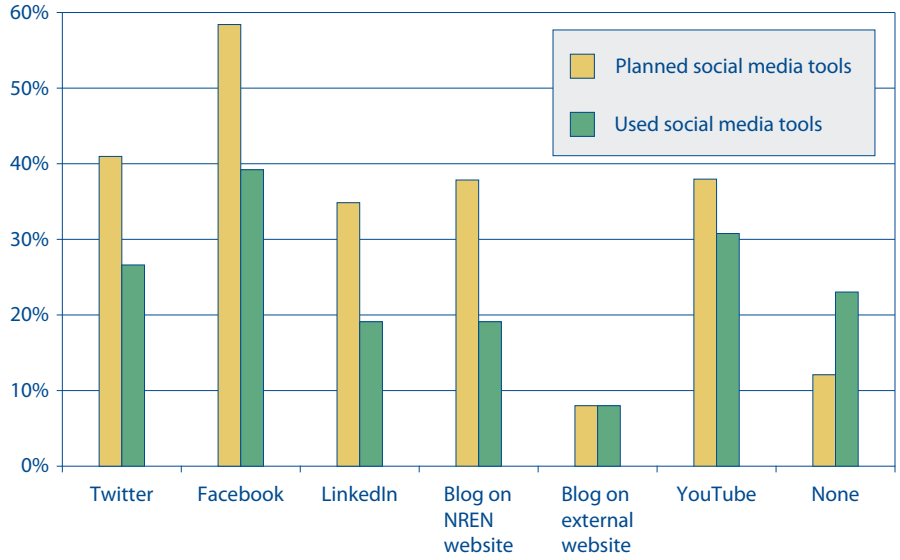


Another interesting area is the use of social media. An increasing number of NRENs intend to use, or already use, social media in their communication activities.

The use of social media by NRENs has grown. In 2009, almost 65% said they did not use social media at all, compared to 23% in 2010. As was the case in 2009, Facebook, YouTube and Twitter are the most frequently used social media tools.

Plans for social media tools in 2011 were also investigated. Almost every NREN is planning to use social media tools in 2010. In addition to Facebook, YouTube and Twitter, the two extra tools to be used most are LinkedIn and website blogs.

Graph 5.8.2 – NREN use of social media tools



NRENs function as centres of excellence, in service of their clients. This year's *Compendium* survey has identified a number of new services being provided by NRENs under the general heading of 'brokerage', i.e. when a NREN uses its expertise and knowledge to engage with the market on behalf of its clients. A prime example of such brokerage is software licensing, whereby NRENs can negotiate bulk deals at the national level for generic, e-learning and other applications. This is probably an area in which NRENs can achieve considerable

savings for their customers and in which there is potential for expansion, especially given the current economic climate.

NRENs are also undertaking framework procurements for network and related equipment. These procurements are often directed primarily at NREN requirements, though client institutions can use the negotiated terms to their advantage by purchasing equipment for their own networks. Maintenance and support contracts are often part of such frameworks; in some cases, there is a demand for the NRENs to manage these contracts as well.

Most NRENs organise national user conferences as well as training courses for specific user-groups. The situation has not changed much since last year and is therefore not included in this year's *Compendium*; information on individual NRENs is available at **www.terena.org/compendium**. A number of NRENs were planning to introduce several new services in 2011. Exchanging information about new services being developed or introduced in some NRENs could be an important way of stimulating the adoption of these services in different countries.

Table 5.8.3 – Special NREN services

Country	Broker services, current	Broker services, planned	Premium services	New services planned for 2011
GÉANT partner countries				
Austria	no			
Belgium	no		consultancy, security audits	Antispam Pro, DNSSEC
Bulgaria	no			
Croatia	no			
Cyprus	no			
Czech Republic	no			
Denmark	no			
Estonia	planned	Federated AAI		
Finland	no		consultancy	HD video conferencing bridge.
France	no			VoIP to PSTN; H323/SIP MCU videoconferencing with RMS
Germany	no			Secure Doodle Service
Greece	Software licencing			We plan to introduce a plethora of SaaS services, PaaS, as well as elastic cloud IaaS, in addition to the currently VPS service offered. Furthermore, we anticipate introducing the 'scientific' SaaS, which will enable researchers to access instances of scientific commercial tools that might not be affordable of a small institution.
Hungary	no			Improvement on several services
Iceland	no			
Ireland	Software licensing, equipment procurement, other		Security audits	National mobile broadband service. National data storage service.

Table 5.8.3 – continued

Country	Broker services, current	Broker services, planned	Premium services	New services planned for 2011
GÉANT partner countries				
Israel	no			
Italy	Limited common procurement for specific projects			HD videoconferencing MCU
Latvia	no		consultancy	
Lithuania	no			
Luxembourg	no			
Montenegro	no			Centralized VPN for telecommuters
Netherlands	planned	Brokering for cloud services such as storage and virtualization, also for SaaS services including Google Apps, Sakai, etc.		SURFconext, Mobile
Norway	Software licensing, equipment procurement		consultancy, security audits	Lecture storage and distribution infrastructure, High-Availability infrastructure for services, Unified Communication infrastructure
Poland	Equipment procurement		consultancy ,security audits	
Portugal	no			Storage
Romania	no			
Slovakia	no			
Slovenia	no			Ethernet Private Line Service, Cloud Storage, Cloud Computing, Filesender, LDAP/IdP hosting, Radius hosting
Spain	Software licensing, equipment procurement		consultancy	1. Remote monitoring of services in our constituency, plus a panel to access data about services and manage them. 2. Wavelengths over the new DF network, RedIRIS-NOVA.
Sweden	no			
Switzerland	no			Group collaboration service
Turkey	no			
United Kingdom	Equipment procurement			

Table 5.8.3 – continued

Country	Premium services	New services planned for 2011
Other countries		
Azerbaijan	consultancy, security audits	eduroam, Identity Federation
Georgia	consultancy	
Serbia	consultancy	
Brazil		Telepresence
Canada		Peering service with major content providers including Google and Amazon
Kazakhstan		KazRENA already issues ISIC/ITIC cards for Kazakhstan University students and teachers. KazRENA is currently planning to introduce eduroam.
Korea		New TTS(NREN Information Management System), etc
Kyrgyzstan	consultancy	Housing
New Zealand		Aggregated Commodity Internet

6 FUNDING AND STAFFING

Some NRENs provide services only to their country's research and/or education community. Others provide additional services; for example, they administer the country-code top-level domain, or they connect companies and/or institutions outside the research or education community. To enable comparison, we asked the NRENs covered by this 2011 edition of the *Compendium* to provide information only about their activities for national research or education communities. We refer to such activities simply as 'NREN activities'.

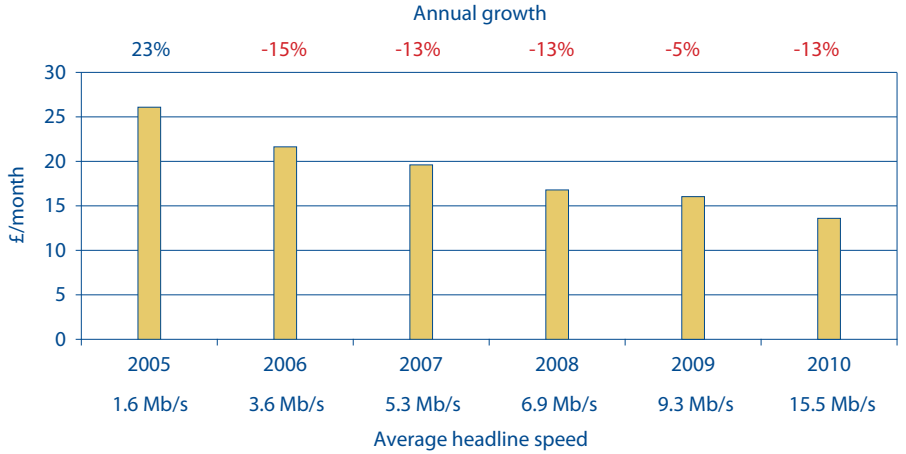
Below, Section 6.1 gives an overview. Section 6.2 details the considerable differences in the number and types of staff that NRENs employ and attempts to explain some of these differences. Section 6.3 provides information on, and explains the variety of, NREN budgets. Sections 6.4 and 6.5 give further information on income sources and expenditure categories, respectively.

6.1 Overview

It is almost impossible to compare NRENs by staff or budget size, because their budgets are variously structured, depending on their tasks, while their funding also differs greatly.

Comparing 2011 budget data with those from previous editions of the *Compendium* reveals that NREN budgets tend to be relatively stable; any year-to-year fluctuations depend on whether an important investment is made in a particular year. The overall trend is that, each year, NRENs are able to deliver more bandwidth and more services for roughly the same amount of money as the previous year. This reflects a continuing trend in the Internet sector, where the price per megabit of bandwidth continues to fall. Graph 6.1.1 illustrates this with an example from the UK.

Graph 6.1.1 – Average monthly cost of a residential fixed broadband connection in the UK*



As in 2010, the overall budget figures show that NRENs are not (yet) significantly affected by the current economic crisis. The budget of the Belgian NREN, Belnet, was reduced, but this was due to heavy investments in 2010 that were not needed in 2011. Greece deserves special mention: following a 25% budget cut in 2010, there was a further 13% cut in 2011. JANET(UK) was confronted with a relatively large budget cut of over 9% in 2011. Some NRENs were able to obtain budget increases, but most budgets remained at 2010 levels. Several NRENs increased their staff size, a notable exception being Lithuania, with sharp cutbacks in staff in both 2010 and 2011.

The economic crisis has not (yet) had an impact on overall staff size. In the GÉANT partner countries, the combined budgets and the total number of NREN-employed staff increased in 2008. This was mostly related to major infrastructural investments in some countries. In other GÉANT countries there have been similar investments over the last five years, coupled with the connectivity upgrade that is being offered by the GÉANT backbone. Taken together, these infrastructural investments have led to transmission cost savings. However, the infrastructural

* Source: Ofcom/operators.
Note: includes estimates where Ofcom does not receive data from operators; includes VAT.

improvements, coupled with innovations in the area of authentication and authorisation, have also enabled a new generation of networked services, which have required some increases in staff size over the past year.

Although it is impossible to make general recommendations on NREN funding mechanisms, a model that in some way involves the various stakeholders in an NREN would seem to provide the best guarantees for its continued success. In their respective fields, many NRENs are engaged in innovations, which are often steered by dedicated funding mechanisms. It is important for NRENs to use such funds to their advantage wherever they exist.

6.2 Staffing

Graph 6.2.1 (right) gives an overview of the staff that are directly employed in NREN activities, as well as subcontracted staff, in full-time equivalents (FTE). Graph 6.2.4 provides similar information specifically for technical staff. The data is presented in this way because many NRENs use subcontractors; therefore, staff size alone is not a reliable indicator of the total amount of person-power available to an NREN.

As in previous years, there are considerable differences from NREN to NREN, not only in the number of staff employed but also in their set of skills. One explanation for these differences is that, in some NRENs, the research network is a service provided by a parent organisation; therefore, it is not possible for all such NRENs to specifically estimate the non-technical staff time (e.g. in accounting, human resources, etc.) devoted to NREN activities. This partially explains why some NRENs have a higher ratio of technical to total staff than others.

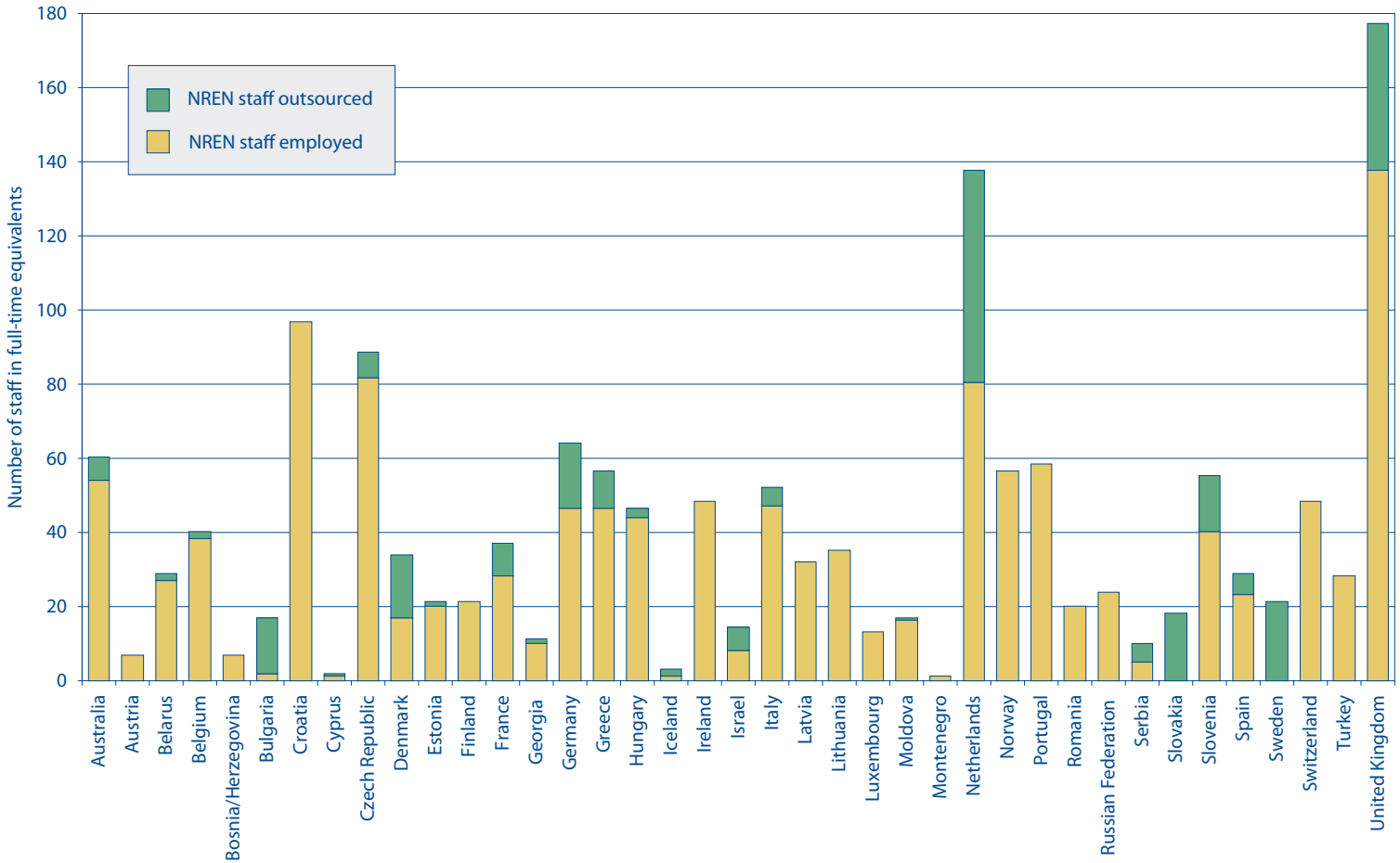
NRENs differ considerably in the tasks they perform: for example, some provide connections to metropolitan area networks (MANs) or to access networks, which in turn connect institutions. Other NRENs connect institutions directly, and some manage MANs themselves. The connection policies of NRENs also differ with respect to secondary and primary schools, for example. This affects the remit of the NRENs and explains some of the differences seen in staff numbers in Graphs 6.2.1 and 6.2.4.

Finally, some NRENs provide extensive support to individual end-users at institutions, some provide limited customer support, and many have service levels that are somewhere in between. This factor can have a significant effect on staff levels.

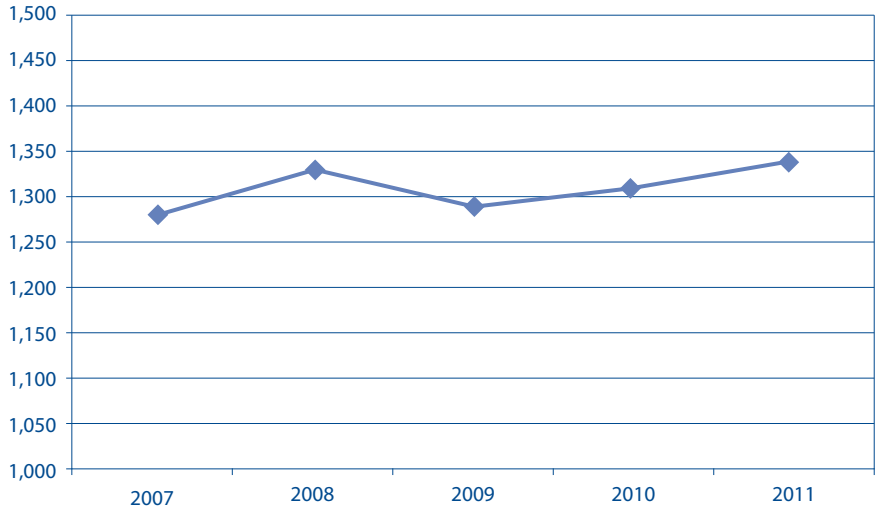
Graph 6.2.2 appears to indicate that the economic crisis has not (yet) had an impact on overall staff size. In the GÉANT partner countries, the total number of NREN-employed staff increased in 2008. This was mostly related to major infrastructural investments in some countries. In 2009, total staff size decreased,

though in 2010 and 2011 it increased again slightly. Financially, these increases were more than compensated by the fact that the improvements in infrastructure were coupled with cost savings, as illustrated by Graph 6.2.3 and the graph in Section 6.5.

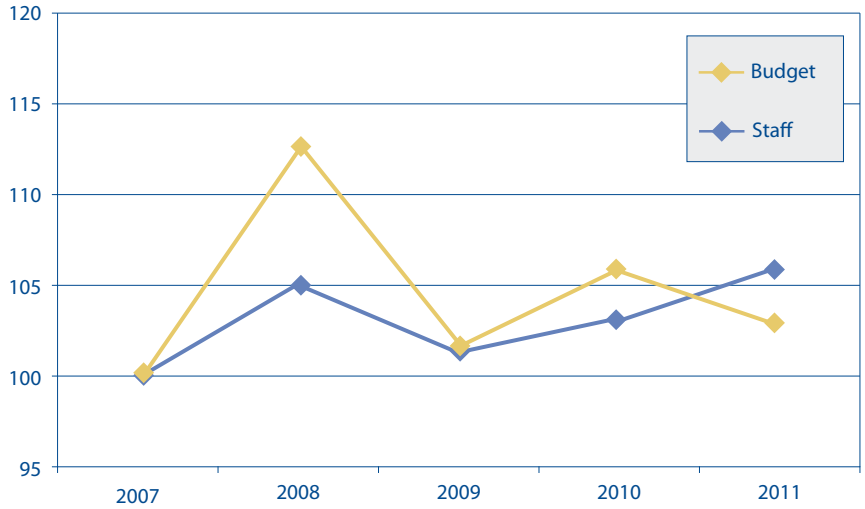
Graph 6.2.1 – Total NREN staff in FTE



Graph 6.2.2 – Total NREN staff in GÉANT partner countries, 2007- 2011[1]



Graph 6.2.3 – Total NREN budgets and staff size in GÉANT partner countries, 2007 – 2011, indexed on 2007 (=100)

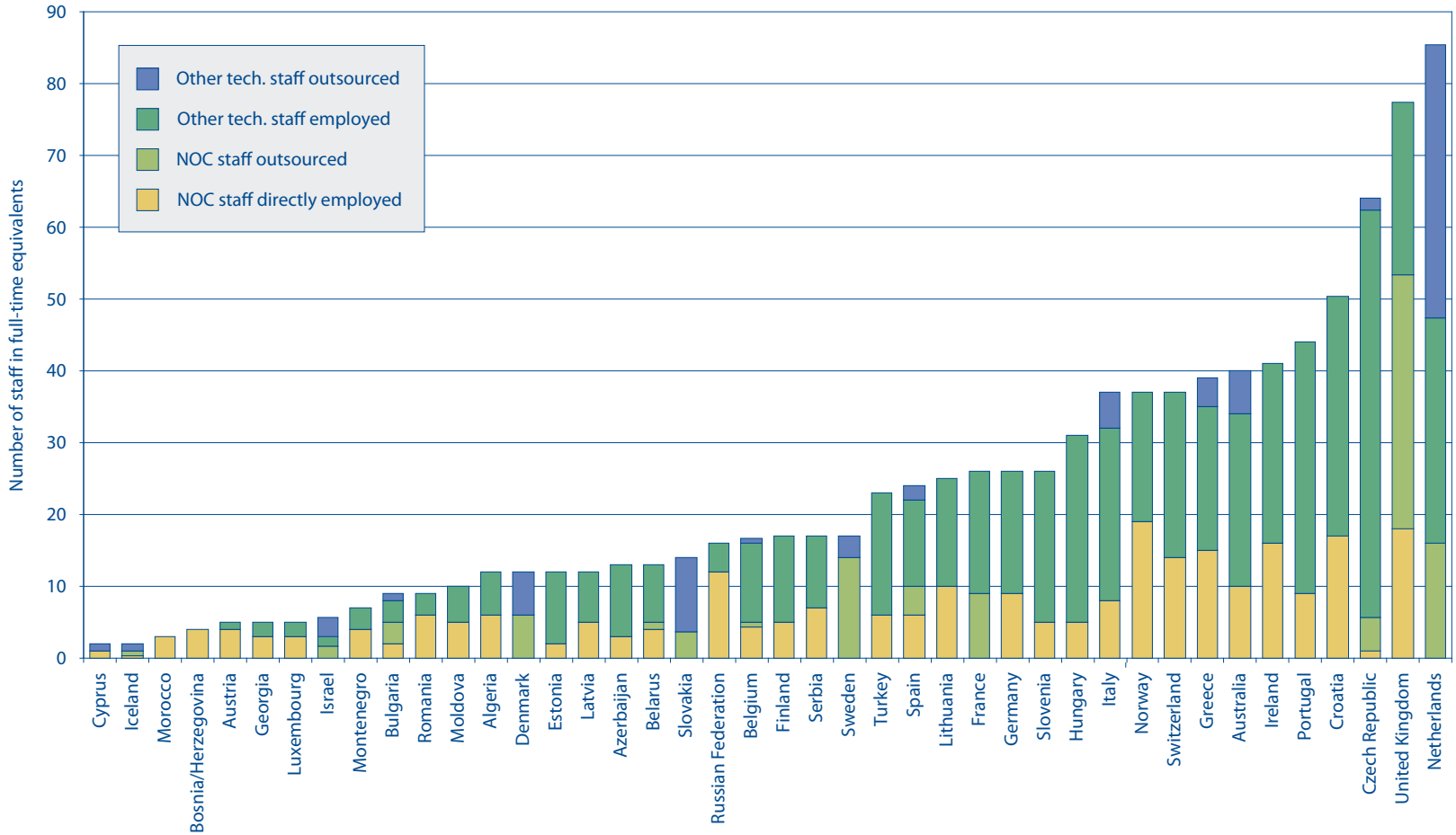


Please note that it is impossible to discern a trend for the situation in the other (i.e. non-GÉANT partner) countries, because they submitted insufficient data.

Graph 6.2.3 (right) compares budget size and staff size, indexed on 2007 (=100). This illustrates the points made above in this section. In 2008, there was a relatively large increase in total NREN budgets, which was related to major infrastructural investments in some GÉANT partner countries. These infrastructural investments led to transmission cost savings. However, the resulting infrastructural improvements, coupled with innovations in the area of authentication and authorisation, also enabled a new generation of networked services. Where these services are administered by NRENs, they require more staff.

[1] Excluding data from Poland.

Graph 6.2.4 – NREN technical staff in FTE



6.3 Total budgets, 2006-2008 and 2009-2011

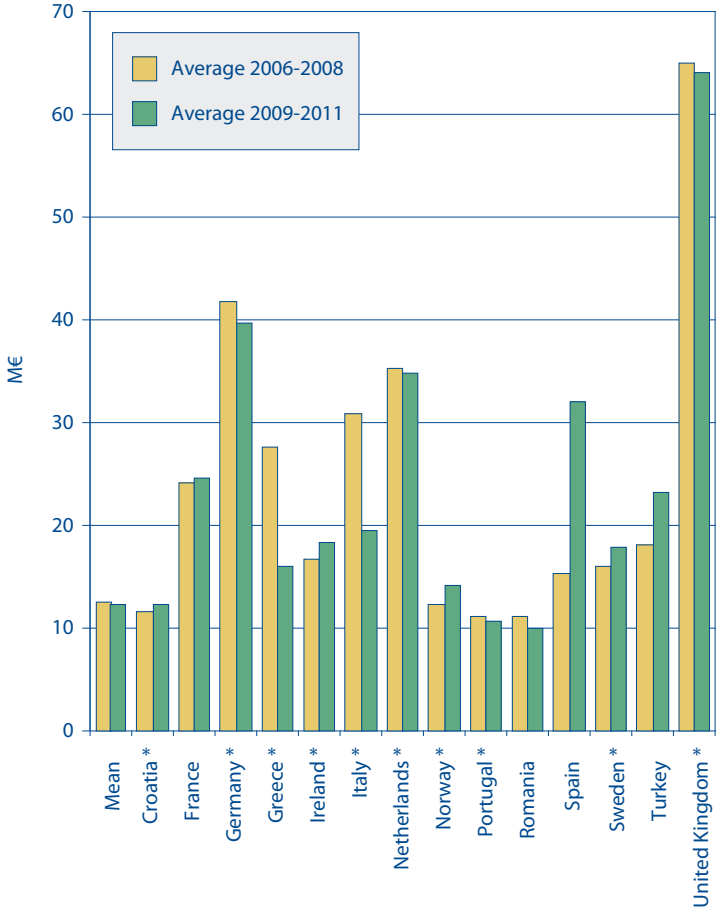
NREN budgets may fluctuate due to annually varying investment levels. In order to filter out as much of this effect as possible, in Graphs 6.3.1 and 6.3.2 (right, for the GÉANT partner countries) we compared the total NREN budgets for two three-year periods: 2006-2008 and 2009-2011. Note that for JANET(UK) the financial year is from August to July; thus, its 2011 budget is actually its 2010/2011 figure.

The total annual budgets are shown in Graph 6.3.4, together with the growth in GÉANT traffic[2].

For several reasons (see bulleted list below) it remains difficult to directly compare budgets. We asked the NRENs whether their submitted budget figure includes the EU grant for GÉANT activity. For some NRENs, this is the case; for others, this grant is shown not as part of the budget but as a reduced cost. In Graphs 6.3.1 and 6.3.2 (right), the NRENs that include the GÉANT subsidy in their budget figure are marked with an asterisk.* As shown in Section 6.4, the proportion of funds received from the EU (though not always exclusively for GÉANT) differs considerably. There are other reasons why comparison is difficult:

- Regional and/or metropolitan area networks (RANs/MANs) are funded differently in different countries;
- In some countries, clients pay for their link to the nearest NREN point of presence; in others, the NREN pays for this;
- Some NRENs spend a large part of their budget on connecting primary and secondary schools; others do not or may take this separately into account;
- There are large differences in how staff are paid. In the GÉANT area, one NREN spends only 2% of its budget on staff, whereas another spends 59% of its budget on this. In this context, it should be noted that some NRENs have staff who are not paid from the NREN budget. There may be differences in other expenditure categories as well.

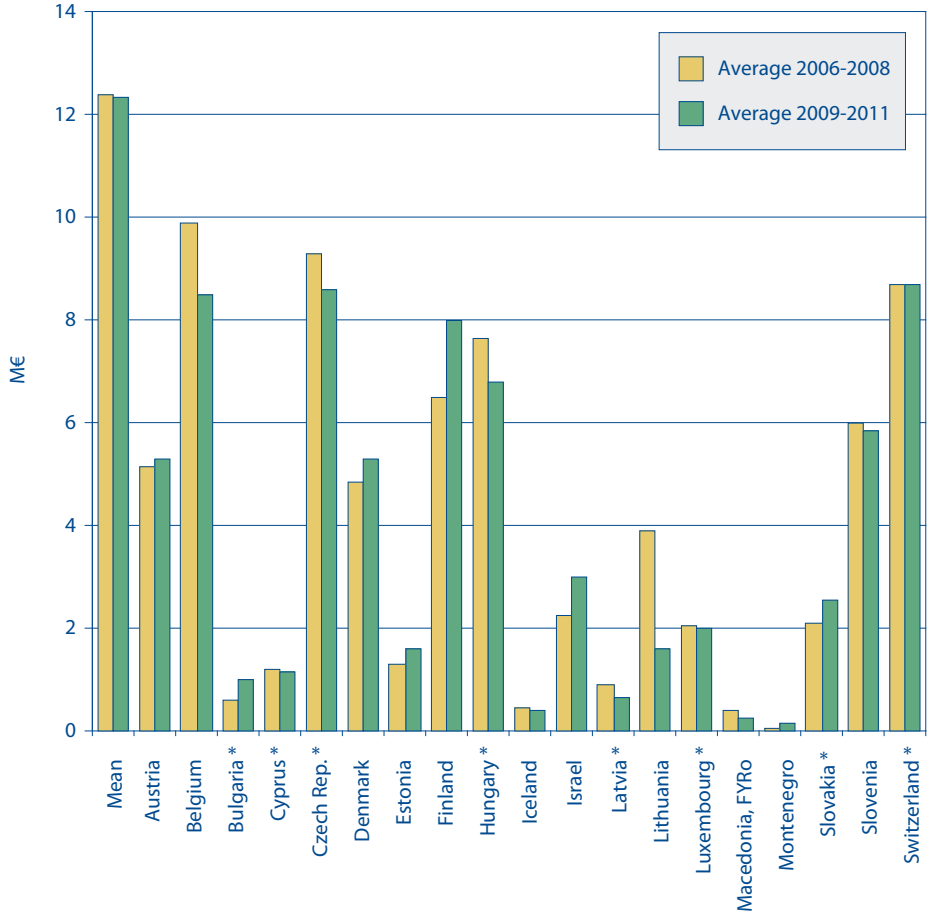
Graph 6.3.1 – Total budgets, 2006-2011 averages, GÉANT partner countries with annual budgets > 10 M€



[2] Traffic through the GÉANT network is only one of many components of a NREN's traffic. Nevertheless, it is used here as a comparator because it reflects the overall activity of an NREN and is measured centrally.

* Budget includes GÉANT subsidy.

Graph 6.3.2 – Total budgets, 2006-2011 averages, GÉANT partner countries with annual budgets < 10 M€



As Graphs 6.3.1 and 6.3.2 clearly show, most NREN budgets have decreased slightly over the past few years. Notable exceptions are the relatively large budget decreases in Belgium, Italy, Greece and Lithuania, and the relatively large increase in Spain. In these cases, both the increases and the decreases are related mainly to major one-time infrastructural investments. In 2011, major budget increases (of at least 20% with respect to the 2010 level) took place in Denmark and Estonia.

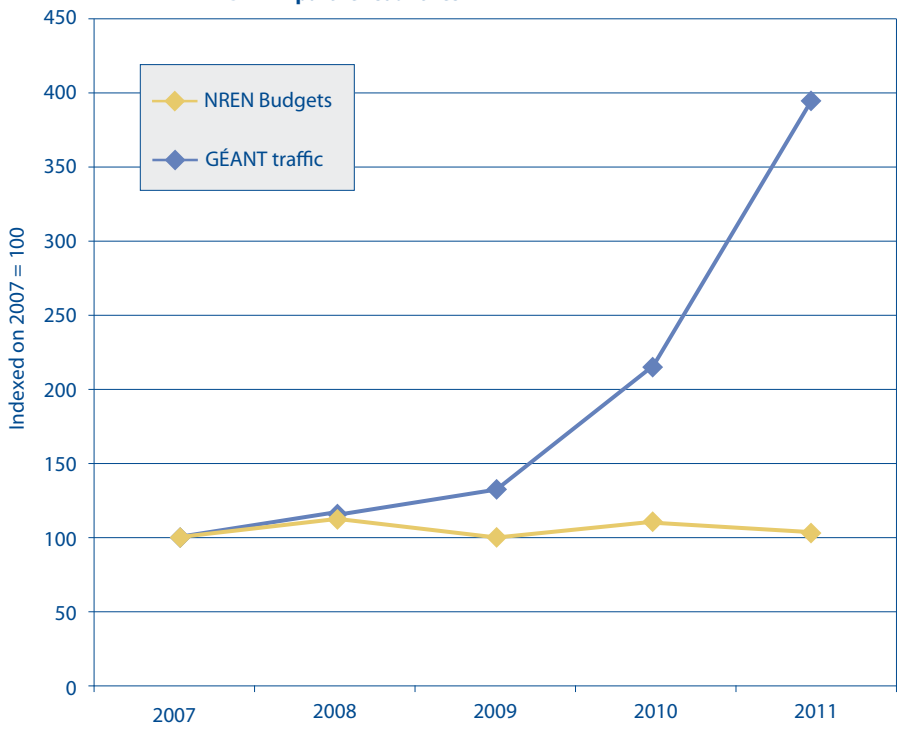
The overall trend is also illustrated by Graphs 6.3.3 and 6.3.4, which confirm that the total budget for the GÉANT partner countries[3] has remained stable over the past five years at approximately 400 million euro. The notable exception, the small peak in 2008, was due to major investments in network infrastructure in Greece, Italy and Romania.

Graph 6.3.3 – NREN budgets, GÉANT partner countries, indexed on 2006 (= 100)

[3] Excluding data from Poland.

Traffic has quadrupled since 2007, as illustrated by the figures for traffic on the GÉANT backbone, which are plotted in Graph 6.3.4 (below):[4]

Graph 6.3.4 – Total NREN budgets and traffic growth, 2007-2011, GÉANT partner countries



As Graph 6.3.4 clearly shows, the investments in infrastructure upgrades that have been made in many countries in recent years have enabled further traffic growth for roughly the same amounts of money each year. This has also enabled growth both in the diversity and in the number of services offered on the network.

The data from the non-GÉANT countries is not sufficiently time-consistent to allow it to be presented in the same form as that from the GÉANT partner countries.

[4] The 2011 traffic data are an estimate, based on an extrapolation of the figures for the first six months of 2011.

For several of the non-GÉANT partner countries, present funding levels are likely to be insufficient for them to bridge the 'digital divide', even in light of the falling prices of connectivity in recent years.

6.4 Income sources

NRENs are funded in various ways: some receive all of their funding directly from the national government; others are funded entirely by their users (who may, in turn, be government-funded to some extent). Between those extremes there are many variants. Graphs 6.4.2 and 6.4.3 indicate what percentage of NREN funds comes from which source. Note that in many cases (see also Graphs 6.3.1 and 6.3.2) the amount of funding received from the EU is not included.

Although it is impossible to make general recommendations on NREN funding mechanisms, a model that in some way involves the various stakeholders in an NREN would seem to provide the best guarantees for its continued success. It should be noted that, in their respective fields, many NRENs are engaged in innovations, which are often steered by dedicated funding mechanisms. It is important for NRENs to use such funds to their advantage wherever they exist.

In this context, it is still relevant to cite the September 2007 EARNEST Report on Organisational and Governance Issues, by Robin Arak.[5] The EARNEST Summary Report[6] includes the following summarised recommendations from that study:

Partial funding by connected institutions is a viable model, but it needs to be treated carefully. For upgrades of the network and for the development and deployment of innovative services, a certain amount of central funding is often indispensable.

If connected institutions are charged for the connectivity and services provided by NRENs, this should be done in such a way that it is not a disincentive for innovation.

[5] TERENA, Amsterdam, 2007, ISBN 978-0-77559-11-6, www.terena.org/publications/files/EARNEST-organisation.pdf

In a changing economic environment, it is important that the development and enhancement of research and education networks is planned on an appropriate time scale and that forward budget planning over several years is carried out, so that the necessary resources, both human and financial, are available when required. EARNEST found that many national research and education networking organisations only plan budgets on an annual basis. That is not sufficient for planning major network and service infrastructure developments. Involving major users of research and education networks in the planning is also important, particularly when some of them may need additional dedicated connections or services, or significant enhancements to existing infrastructure, to achieve their research and education objectives.

NRENs should reassess their planning and budgeting periods. They should plan and budget over a period of several years, in line with best practice in the planning of major infrastructure projects.

For this edition of the *Compendium*, NRENs were asked whether they can make use of multi-annual budgeting. Of the GÉANT partner NRENs, 46% confirmed that they can, whereas the remaining NRENs cannot. Table 6.4.1 (below) gives a complete overview:

Table 6.4.1 – Multi-annual budgeting

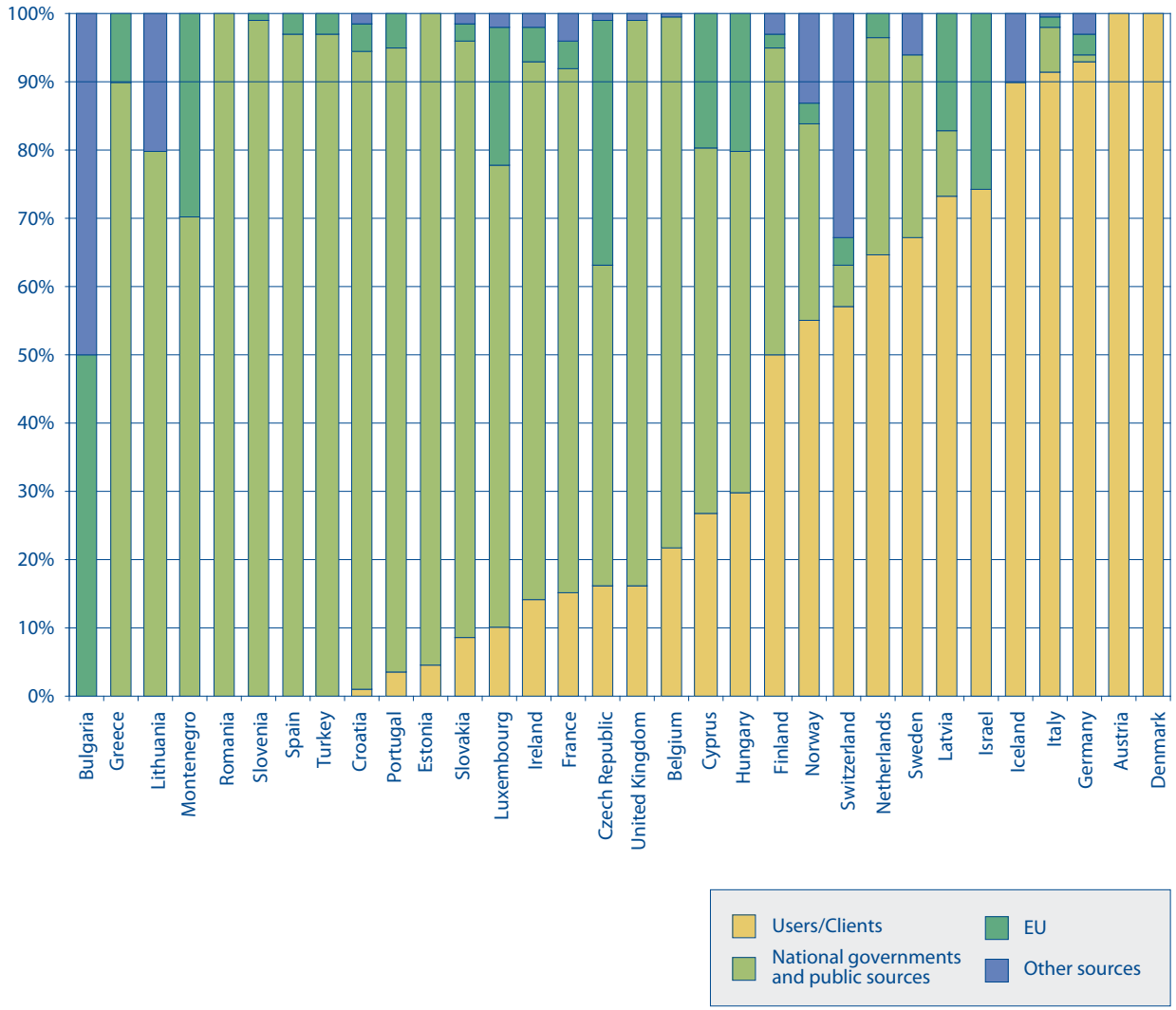
Country	Multiyear?	How?
GÉANT partner countries		
Austria	yes	
Belgium	yes	Belnet develops multi-annual budgets via accountancy software which takes into account our multi-annual financial contractual engagements. Positive amounts are automatically carried forward to the following year.
Croatia	yes	We make 1 year plans, and an extra 2-year projection within the Central State Budget.
Czech Republic	yes	The multi-annual budget construction is implicated by long-term project subsidies, which represent the main source of incomes.

Table 6.4.1 – continued

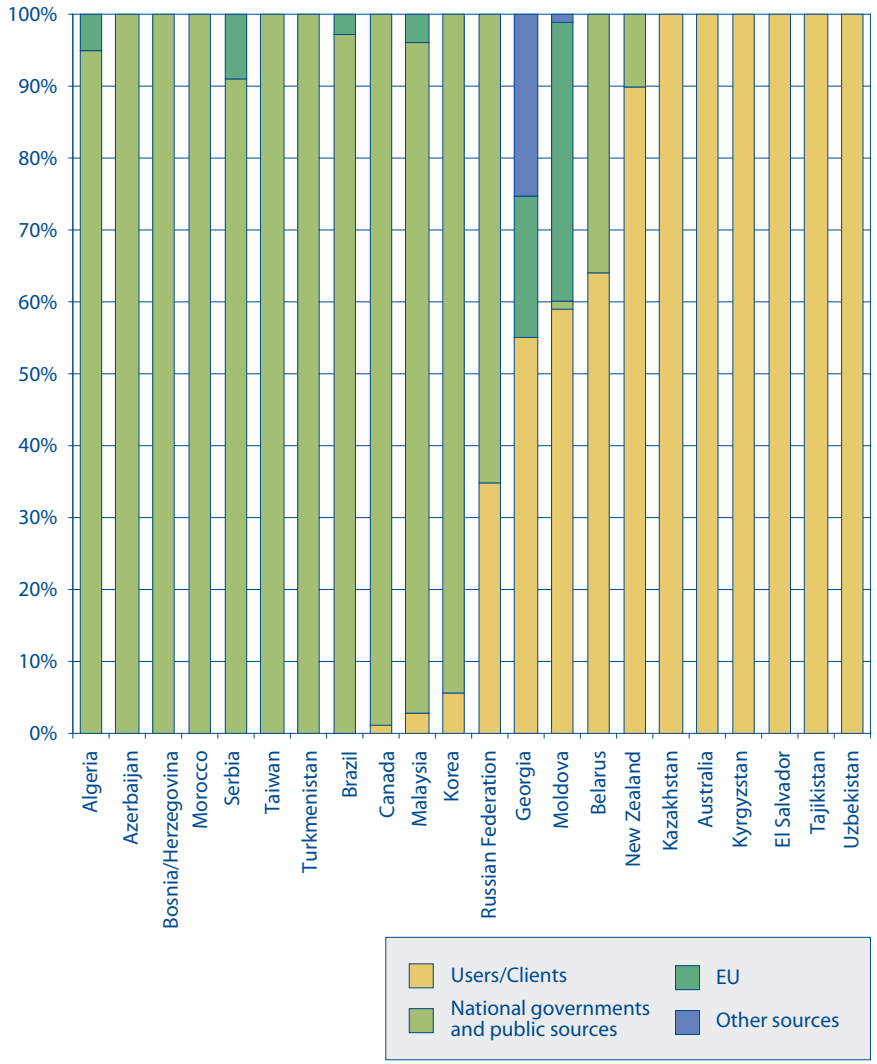
Country	Multiyear?	How?
GÉANT partner countries		
Finland	yes	Limited possibility for multi-annual plans in major investments such as network upgrades, together with Ministry of Education (utilizing ministry strategies etc.).
France	yes	
Germany	yes	
Hungary	yes	NIIFI has a rolling 3-year Strategy Plan; for national and international projects, the plans may span multiple years.
Iceland	yes	Can be done, if deemed necessary.
Ireland	yes	Multi-annual plans are discussed with the Finance Subcommittee, Board of Directors and grant providers.
Netherlands	yes	Each year, a budget is made for a period of 4 years. Long-term agreements are closed with customers.
Norway	yes	UNINETT is a limited company and follows the Norwegian rules and regulations on companies. UNINETT has a long-term policy of non-profit, but may run a surplus or a deficit from year to year. Multi-annual plans are typically used for larger programmes or procurement of infrastructure.
Portugal	yes	We make multi-annual budget and activity forecasts. This is complemented by a yearly detailed budget and plan, which has to be approved by FCCN's General Council.
Spain	yes	
Switzerland	yes	The budgeting process is done by the management of SWITCH. The budget needs to be approved by the Foundation Council. Customers are also represented in the Foundation Council. The responsibility of the Foundation Council is to assure that the mission of the foundation is accomplished.
United Kingdom	yes	Reducing. Dependent on UK economy.

[6] TERENA, *Innovation, Integration and Deployment: Challenges for European Research and Education Networking Innovation* (Amsterdam: 2008), ISBN 978-90-77559-18-5, www.terena.org/publications/files/EARNEST-Summary-Report.pdf, p. 31.

Graph 6.4.2 – Income sources, GÉANT partner countries



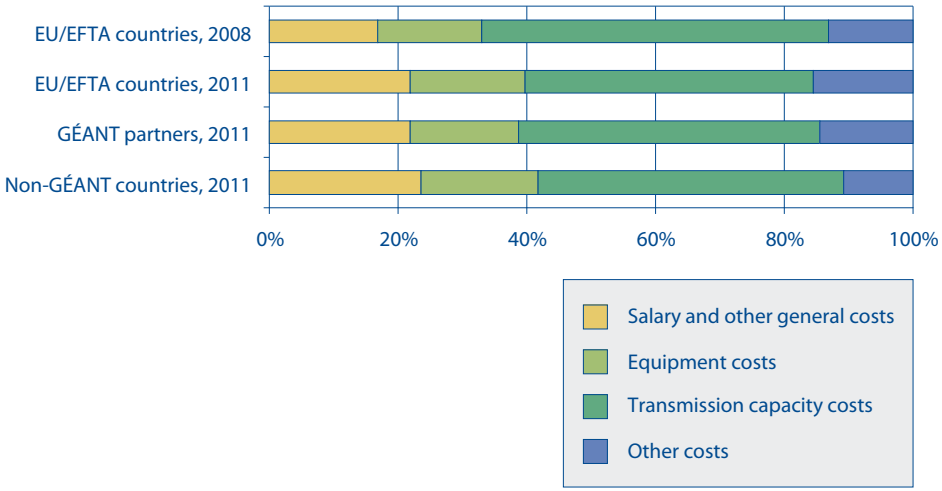
Graph 6.4.3 – Income sources, other countries



6.5 Expenditure by category

Graph 6.5.1 (below) shows the average percentage of NREN income spent on various categories of costs. The averages of the GÉANT partner countries and the other countries are very similar. Note, however, that there are considerable differences between individual NRENs in this respect.

Graph 6.5.1 – Expenditure by category



On average, in 2011, the expenditure in the EU/EFTA countries on transmission cost was slightly lower than the expenditure in all GÉANT partner countries on the same item. Compared with 2008, the proportion of transmission capacity costs in the EU/EFTA countries has decreased considerably, from 54% of total expenditure to 45%. The proportion of salary and others costs has increased (although this does not necessarily mean that salaries have increased in absolute terms). The proportion of equipment costs has remained the same.

APPENDICES

1 Major changes in NRENs

The table below reproduces the full replies from NRENs to the question "please give us a short description of major changes that occurred in your organisation and/or services during the past year or that you foresee for the coming year (structural changes, changes in your mandate or remit, major technology upgrades, changes in the user base, etc.)". Note that the non-response of some NRENs does not necessarily mean that there were no major changes to their networks. The material has been lightly edited in some cases for consistency and clarity.

Section 1.4 includes a summary of the answers.

Country	NREN	Changes
GÉANT partner countries		
Belgium	Belnet	Staff size increased in order to remove bottlenecks and single points of failures inside our organisation. We moved in December 2010 to a new office building with a big improvement of facilities (meeting rooms that will give us a chance to organise and give more workshops).
Croatia	CARNet	CARNet is continuing implementation of several key infrastructure projects to provide optical connectivity of its user institutions to the network with dark fibre. Also, a major VoIP project is being implemented, as well as operational work of the National CERT. HD MCU and other videoconferencing equipment (IPv6 enabled) have been tested in a pilot phase. The IPv6 protocol has been enabled at the levels of the backbone, end users and services.
Cyprus	CYNET	CYNET has upgraded its connection with GÉANT from 310 Mbps to 1+1 Gbps. CYNET is in the process of creating 2 more PoPs in two major cities in Cyprus. CYNET has increased its membership and its bandwidth provision to all members, at the same time decreasing its prices.
Denmark	UNI-C	On 1 January 2011, Forskningsnettet changed its strategic focus to concentrate on delivering infrastructure to education and science. We no longer offer content services or services for e-learning.
Estonia	EENet	1) EENet administered the top level domain .ee from its creation in 1993 until July 2010. Due to the reform initiated by the Ministry of Economic Affairs and Communications, since July 2010 the TLD .ee has been administered by the Estonian Internet Foundation (www.eestiinternet.ee). As a result of this reform, a fee was set on .ee domain names and registration services were opened to foreign entities and persons. EENet became an accredited Registrar for educational, research and cultural institutions. Delivery of the .ee register with 78 000 domain names was the most labour-intensive work in 2010. 2) New statutes were enacted due to some structural changes in April 2011.
Finland	Funet	New university legislation, separating universities from the state, and several university mergers.
Greece	GRNET S.A.	GRNET S.A. has already acquired 15-year IRUs for dark fibre (DF) links for the largest part of its core and access network. As of 15 July 2011, GRNET owns 8950 km of dark-fibre pairs. Alcatel DWDM equipment has been installed in our network backbone and in metropolitan area networks in Athens and Salonica. GRNET S.A.'s goal with the planned migration to owned-fibre infrastructure is to operate a 'hybrid' network that will continue to provide sound-production-quality IP services to all users and at the same time provide Layer 1/Layer 2 services to its clients. In 2010, GRNET extended its core and access network by connecting more than 5 clients with dark fibre pairs and upgraded part of it by connecting GRNET power users to 10 Gbps. Furthermore, innovative services were designed and deployed. In the coming two years, the GRNET network will be redesigned and upgraded (GRNET-4), taking into account next-generation networking trends and technologies. GRNET-4 will be based on 3 basic service layers: the optical service layer, the carrier service layer and the IP service layer. GRNET data centres will be fully equipped with IT equipment, facilitating the provision of existing services to more users as well as the deployment of new services (SaaS, PaaS cloud IaaS and 'scientific' SaaS services). An HPC infrastructure and an energy efficient (green) data centre is to be installed, aiming at a low PUE through the use of green technologies and renewable energy sources.

Country	NREN	Changes
GÉANT partner countries		
Hungary	NIIF/ HUNGARNET	1. NIIFI was previously operating under the umbrella of the Ministry of Communication and Informatics, then the Ministry of Economy and Transport, from 2008 the Office of the Prime Minister and from 2010 the Hungarian Academy of Sciences. Since 2011, it has been operating under the Ministry of National Development. 2. The research network in Hungary has been continuously developing during the last few years (backbone and access network extensions and upgrades, plus international connectivity upgrade to GEANT+). No further organisational changes were foreseen for 2011, while a considerable technical development (reconstruction and upgrade of the internal NIIF/ Hungarnet network) was ongoing during 2009-2011 (HBONE+ project, and related network and service development activities). No significant change in the user base is forecast.
Ireland	HEAnet	The role of Client Services Management has been introduced as a fundamental part of HEAnet operations. HEAnet has implemented a Client Services Strategy, thereby ensuring that HEAnet continues to achieve a high level of alignment with its client community needs. HEAnet carried out a formal programme of Client Service Reviews across the 2010 calendar. Longer-term initiatives have been reflected in some immediate changes to the day-to-day activities of HEAnet, including: • Implementation of an agreed communications protocol founded on a shared understanding of the clients and their end-users; • Increased level of client interaction via Client Service Reviews and services-related meetings; • To serve as a conduit for cllients to provide strategic input into the service planning phases of key projects such as Data Storage, Data Centre Feasibility, Next-Generation Network and Wireless/Mobility Phase; • Adoption of appropriate ITIL V3 service management principles • Definition & implementation of a new Client Requirements Process. Client Communications is an integral part of the role, and we have adopted a multi-channel approach using a variety of tool and methods. The HEAnet website is the repository of all public facing documentation and incorporates the use of an RSS news feed to alert clients of updates and important initiatives.

Country	NREN	Changes
GÉANT partner countries		
Ireland (continued)		Emails to specific stakeholders and the distribution of traditional paper-based material such as the Newsletter and the Annual Report will also continue. These communication mediums all supplement the face-to-face events that are at the centre of our Client engagement approach, and the Annual Networking Conference remains a key event.Services delivery is at the heart of the Client Services Management function, which this year saw the successful delivery of a number of new client services including FileSender and Media Hosting Service, as well as the launch of Edugate at our National Networking Conference in November 2010.
Israel	IUCC	We are involved in a tender to replace all our university border routers, as well as a tender to upgrade all our internal (national) links to 10 Gb/s. All this should be completed by the end of 2011.
Latvia	SigmaNet	No major changes have happened to SigmaNet in the last year. The GEANT connectivity is still 2.5 Gb/s, including 175 Mb/s commodity traffic. We have successfully established the IPv6 and provide it to our customers.
Macedonia, FYRo	MARNet	In September 2010, the Macedonian Parliament adopted the law for MARNet by which the NREN is established as an independent public body. In January 2011, a Management Board proposed by the Rectors' Conference of Public Universities and relevant ministries was appointed by the Government. In February 2011, a director was elected through public announcement. The adoption of the MARnet Statute and other relevant ruling documents is in progress, as well as a year programme and financial programme. Transition of the functions from 'old' to 'new' MARnet is in progress.
Malta	UoM/ RicerkaNet	A new building, including the main data centre, is being completed during this year (2011).
Montenegro	MREN	Acquisition of Blade servers and migration of all services to virtual servers
Netherlands	SURFnet	The official kick-off meeting for the GigaPort3 innovation project was held in early 2010. This project is intended to upgrade the existing SURFnet network infrastructure and to integrate it seamlessly with the other ICT infrastructure facilities. One of the results of GigaPort3 is the SURFnet7 network, which builds on the current SURFnet6. The DigiBOB project – which in the past few years has digitised the Netherlands' breast cancer screening programme – was concluded successfully. SURFnet is working with higher education and research institutions and other partners - both in the Netherlands and elsewhere – to develop SURFconext, a new collaboration infrastructure.

Country	NREN	Changes
GÉANT partner countries		
Poland	PIONIER	PIONIER celebrated its 10th anniversary in 2011. We installed a new ADVA optical system on these links: Poznań–Zielona Góra–Wrocław, Poznań–Bydgoszcz–Toruń–Gdańsk, Toruń–Warszawa, Poznań–Łódź, Białystok–Warszawa–Radom–Puławy–Lublin, Warszawa–Radom–Kielce–Kraków and Rzeszów–Kraków. It enables transmission of 80 signals over a single fibre pair.
Portugal	FCCN	At the connectivity services level, 2010 was a year for the completion and operation of the new optical network, covering a major part of the whole NREN. A new tender for leased circuits was launched, to be implemented in 2011, with significant cost improvements. The aggregated installed IP capacity increased, from 42G to 70G, mainly due to upgrades in many dark fibre accesses to 10G. The first CBF connection to Spain, through Valença, was prepared. The second, through Badajoz, remained operational, with no major changes. In the security area there was a huge increase (570%) of the CERT.PT activity, due to the enlargement of its jurisdiction to the whole national cyberspace. At the AAI level, the major development was the rapid increase in the available AAI Identity Providers up to 25 connected entities. In the VoIP area, the main change was a major push towards using ENUM, ending the year with 35 838 numbers published. Other major changes occurred in the application area, with the launch of new media services, i.e. EDUCAST and COLIBRI. EDUCAST is similar to the Swiss SWITCHCAST service, and COLIBRI is a web conference service. The Open Access project (RCAAP), which enables free access to scientific articles produced by the national scientific community, was also quite successful, with a 28% increase in the number of repositories, and a 38% increase in the number of available Portuguese articles. Cooperation with Brazil allowed for an additional 72% increase in the number of available articles.
Romania	RoEduNet	100G lambda installed between two major NOCs: Bucharest and Iasi.
Spain	RedIRIS	In October 2011, the contract of the current leased-capacity backbone (RedIRIS-10) will come to an end. It will be replaced by RedIRIS-NOVA, a dark fibre backbone, which has been contracted for the next 20 years. However, it should be noted that the dark fibre for the Canary Islands and Extremadura will not be deployed until 2012, and that so far it seems there will be no dark fibre, even in 2012, for the Baleares (Balearic islands).
Switzerland	SWITCH	The SWITCH strategy 2020 was approved. It will lead to changes in the organisational structure and changes in the mandate in the coming years, starting in 2011.
United Kingdom	JANET(UK)	We have made and will continue to make organisational changes to ensure that we are best able to deliver the required services in the developing financial situation.
Other countries		
Algeria	CERIST	Realisation of a new backbone with 10 PoPs and Giga link between PoPs. Upgrade of connection of all connected sites to FE link with capacity between 100 and 10 Mb/s. Setting up of an mpls architecture on the backbone with IPv6 service.
Moldova	RENAM	Past year: Implementation of the 10 Gb/s links to the GÉANT Network via RoEduNet and 10 Gb/s links to RoEduNet Local ISP as backup facilities. New Cisco Systems routing equipment with 10 Gb/s ports was installed in the central communication node in Chisinau. New dark fibre links were installed in Chisinau. Implementation of eduroam®. MAN that allows widening of the own optical infrastructure up to 65 km. Coming year: deployment of videoconferencing service.
Serbia	AMRES	AMRES has become an official legal entity. Several preconditions to becoming fully operational are in progress.
Australia	AARNet	During the course of 2010, AARNet moved from an outsourced optical NOC to an entirely insourced NOC, staffed 24/7 by 8 FTE on shift duty and a dedicated NOC Manager and spread across two locations (Perth and Sydney). 2011 and 2012 will see substantial fibre and DWDM footprint upgrades, as we light the DWDM system from Perth to Adelaide (approx. 2000 km) and provide fibre connectivity to a number of locations that were previously not serviced by our optical network, such as Darwin and far northern Queensland. One of the more noteworthy sites that will receive vastly upgraded connectivity is the Australian candidate site for the Square Kilometre Array (SKA), which, although more than 800 kilometres from the nearest capital city in Australia's outback, has been connected with fibre and will be provisioned as a DWDM system over the next few months.

Country	NREN	Changes
Other countries		
Brazil	RNP	In 2010, the Inter-ministerial Programme that funds RNP, which originally included the Ministries of Science and Technology and of Education, was extended to include the Ministry of Culture, increasing our number of clients. Additionally, RNP carried out a significant enlargement of its national backbone, increasing the capacity by 280%. Currently, 24 of our 27 PoPs are connected at capacities of 3 Gb/s and 10 Gb/s.
Canada	CANARIE	CANARIE started the offering of full IPv6 commercial traffic in mid 2010. This year, CANARIE is working on providing access to major content providers including Google, Amazon and Microsoft.
Malaysia	MYREN	We implemented the MYREN Phase 2 upgrade in 2010, building our 5 regional PoPs. An additional PoP is scheduled this year. Our membership was extended from only institutes of higher learning to polytechnics and community colleges (40 in total). This and next year we plan to offer more services such as VoIP and video-conferencing services, as well as extending membership coverage to a further 18 sites.
New Zealand	REANNZ	The National Core network supply was transitioned from a vertically integrated service to a layered set of services from different vendors: FX networks provide most core connectivity, Brocade switches, Juniper routers and Dimension Data provide service management. International network transitioned from 155 Mb/s to Sydney and 622 Mb/s to Seattle, provided by Verizon, to a 1 Gb/s service to Sydney and a 1 Gb/s service to Los Angeles, provided by TelstraClear.
Taiwan	NCHC	TWAREN's user base has been slowly and steadily growing. No structural and technological change is planned in the next year.
Uzbekistan	UzSciNet	The external international satellite channel has been closed. The international channel is now organised through Uztelekom.

2 Alphabetical list of NRENs

N.B.: For additional information on these NRENs, see the country entries at **www.terena.org/compendium**

NREN acronym	NREN name	Country
AARNet	Australia's Academic and Research Network	Australia
ACOnet	Österreichisches akademisches Computernetz	Austria
AfREN		Afghanistan
AMRES	Akademska Mreza Srbije	Serbia
ANKABUT		United Arab Emirates
Arandu		Paraguay
ARENA	Armenian Research and Education Networking Association (ARENA) Foundation	Armenia
ARNES	Akademska in raziskovalna mreža Slovenije	Slovenia
ASNET-AM		Armenia
AzRena		Azerbaijan
AzScienceNet	Azerbaycan Milli Elmler Akademiyası Şebekesi	Azerbaijan
BASNET	Setka Natsianalnai Akademii Nauk Belarusi	Belarus
BdREN	Bangladesh Education and Research Network	Bangladesh
Belnet	(NL): Het Belgische telematicaonderzoeksnetwerk, Belnet. (FR): Belnet, Réseau télématique belge de la recherche.	Belgium
BOLNET		Bolivia
BREN	Sdruzhenie Bulgarska Izsledovatelska i Obrazovatelna Mrezha	Bulgaria
CamREN		Cambodia
CANARIE	CANARIE Inc.	Canada
CARNet	Hrvatska akademska i istraživačka mreža - CARNet	Croatia
CEDIA	Consorcio Ecuatoriano para el Desarrollo de Internet Avanzado	Ecuador
CERIST	Centre de Recherche sur l'Information Scientifique et Technique	Algeria
CERNET		China
CESNET	CESNET, zájmové sdružení právnických osob	Czech Republic
CSTNet		China
CUDI	Corporación Universitaria para el desarrollo de Internet	Mexico
CYNET	Kypriako Erevnitiko Kai Akadimaiko Diktio	Cyprus
DFN	Deutsche Forschungsnetz	Germany
DrukREN		Bhutan
e-ARENA	Nacionalnaia Associacia issledovatelskih i nauchno-obrazovatelnih electronnih infrastructur 'e-ARENA'	Russian Federation
eb@le	eb@le	Congo, Democratic
EENet	Eesti Hariduse ja Teaduse Andmesidevork	Estonia
ERNET	Education and Research Network	India
EthERNet		Ethiopia
EUN	Shabaket El Gamaat ElMasria	Egypt
FCCN	Fundação para a Computação Científica Nacional	Portugal
Funet	Funet	Finland
GARNET		Ghana
GARR	Consortium GARR (Gestione Ampliamento Rete Ricerca)	Italy
GRENA	Saqartvelos samecniero-saganmanatleblo kompiuteruli qselebis asociacia	Georgia
GRNET S.A.	Ethniko Diktio Ereynas & Technologias	Greece
HARNET		Hong Kong
HEAnet	HEAnet Ltd.	Ireland
HIAST		Syria
INNOVA|RED		Argentina
INHERENT-DIKTI		Indonesia
Internet2	Internet2	United States
IRANET/IPM		Iran (Islamic Republic of)
ISU		Saudi Arabia
IUCC	Merkaz Hachishuvim haBain Universitai	Israel
JANET(UK)	The JNT Association trading as JANET(UK)	United Kingdom
JGN2plus		Japan
JUNet	Shabakat Aljamiat Al Urduniyeh	Jordan
KazRENA	Qazaqstannyn' bilim beru zhane gylymi kompyuter zhelisin koldanushylar kauymdastygy / Asociaciya polzovateley nauchno obrazovatrlnoi kompyuternoi seti Kazakhstana	Kazakhstan
KENET	Kenya Education Network Trust	Kenya

NREN acronym	NREN name	Country
KOREN	Korea Advanced Research Network	Korea, Republic of
KRENA-AKNET	Kyrgyzskaya Nauchnaya i Obrazovatel'naya Kompyuternaya Set-AKNET	Kyrgyzstan
KREONET	Korea Research Environment Open NETwork	Korea, Republic of
LANET		Latvia
LEARN	Lanka Education and Research Network	Sri Lanka
LERNET		Lao People's Democratic Republic
LITNET	Lietuvos mokslo ir studiju instituciju kompiuteriu tinklas	Lithuania
MAREN	Malawi Research and Education Network	Malawi
MARNet	Makedonska akademska nauchno-istrazhuvachka mrezha	Macedonia, FYRo
MARWAN	MARWAN- Réseau informatique national pour l' éducation, la formation et la recherche	Morocco
MoRENet	Mozambique Research and Education Network	Mozambique
MREN	Crnogorska mreza za razvoj i nauku	Montenegro
MYREN	Rangkaian Pendidikan & Penyelidikan Malaysia	Malaysia
NCHC	National Center for High-performance Computing	Taiwan
ngREN		Nigeria
NiCT	Dokuritu Gyousei Houjin Jyouhou Tuusin Kenkyuu Kikou	Japan
NII	National Institute of Informatics	Japan
NIIF/HUNGARNET	Nemzeti Informacios Infrastruktura Fejlesztesi Intezet / Magyar Kutatasi es Oktatasi Halozati Egyesulet	Hungary
NKLN	National Knowledge and Learning Network	Trinidad and Tobago
NREN	Nepal Research and Education Network	Nepal
OMREN		Oman
PERN	Pakistan Education & Research Network	Pakistan
PIONIER	Polski Internet Optyczny - Konsorcjum Akademickich Sieci Komputerowych i Centrów Komputerów Dużej Mocy	Poland
PNGARNet		Papua New Guinea
PREGINET	Philippine Research, Education, and Government Information Network	Philippines
Qatar Foundation		Qatar

NREN acronym	NREN name	Country
RAAP	Red Académica Peruana	Peru
RADEI	Red Avanzada Dominicana de Educación e Investigación	Dominican Republic
RAGIE	Red Avanzada Guatemalteca para la Investigación y Educación	Guatemala
RAICES	Red Avanzada de Investigación, Ciencia y Educación Salvadoreña	El Salvador
RAU	Red Académica Uruguaya	Uruguay
REACCIUN	REACCIUN: Red Académica de Centros de Investigación y Universidades Nacionales	Venezuela
RedCONARE		Costa Rica
REANNZ	Research and Education Advanced Network New Zealand Limited	New Zealand
RedCyT	Red Científica y Tecnológica - Panamá	Panama
RedIRIS	RedIRIS	Spain
RedUNIV		Cuba
RENAM	Asociatia Obsteasca RENAM	Moldova, Republic Of
RENATA	Corporación Red Nacional Académica de Tecnología Avanzada - RENATA	Colombia
RENATER	Réseau national de télécommunications pour la technologie, l'enseignement et la recherche	France
RENIA		Nicaragua
RENU	Research and Education Network of Uganda	Uganda
RESTENA	Fondation RESTENA, Réseau Téléinformatique de l'Education Nationale et de la Recherche	Luxembourg
REUNA	Red Universitaria Nacional	Chile
RHnet	Rannsókna- og háskólanet Íslands hf (RHnet)	Iceland
RNP		Brazil
RNRT	Secretariat of State for Scientific Research and Technology responsible for the National R&D Network	Tunisia
RNU	Rede Nacional de Ensino e Pesquisa	Tunisia
RoEduNet	Agentia de Administrare a Retelei Nationale de Informatica pentru Educatie si Cercetare - "RoEduNet"	Romania
RwEdNet		Rwanda
SANET	Združenie používateľov slovenskej akademickej dátovej siete - SANET	Slovakia (Slovak Republic)

NREN acronym	NREN name	Country
SANReN		South Africa
SARNET	Academic and Research Network of the Republic of Srpska	Bosnia/ Herzegovina
SigmaNet	SigmaNet, Latvijas Universitātes Matemātikas un Informātikas institūta Akadēmiskā tīkla laboratorija	Latvia
SINET		Japan
SingAREN	Singapore Advanced Research and Education Network (SingAREN)	Singapore
Somaliren		Somalia
SUIN	The Sudanese Universities Information Network	Sudan
SUNET	Det svenska universitetsdatornätet SUNET	Sweden
SURFnet	SURFnet B.V.	Netherlands
SWITCH	SWITCH	Switzerland
TARENA	Tajik Academic, Research and Educational Network Association	Tajikistan
TENET		South Africa
TERNET	Tertiary Education and Research Network of South Africa	Tanzania, United Republic Of
ThaiREN		Thailand
TuRENA	Türkmenistanyň milli ylym-bilim tory	Turkmenistan
TWAREN		Taiwan
UARNet	Derzavne pidpryemstvo naukovo-telekomunikacijnyj centr 'Ukrainska akademichna i doslidnytska mereza' IFKS NAN Ukrainy	Ukraine
ULAKBIM	Ulusal Akademik Ag ve Bilgi Merkezi	Turkey
UNI-C	Danish Research Network, UNI • C	Denmark
UniNet		Thailand
UNINETT	UNINETT AS	Norway
UoM/RicerkaNet	Servizzi tat-Teknoloġija ta' l-Informazzjoni, L-Università ta' Malta/RiċerkaNet	Malta
URAN	Asociacija Korystuvachiv Ukrainskoji Naukovo-Osvitnioji Telekomunikacijnoji Merezhi	Ukraine
UzSciNet	O'zbek ilmiy va o'quv tamog'i	Uzbekistan
VinaREN	Mang Nghiên cúu và Đào tao Viêt Nam	Vietnam

3 Glossary of terms

Terms not listed in this glossary are either explained in the main text or presumed to be commonly understood.

AAI	Authentication and Authorisation Infrastructure: a term used for systems supporting the process of determining both (1) whether users are who they declare themselves to be (authentication) and (2) that they have the appropriate rights or privileges necessary to access a resource (authorisation).
APAN	Asia-Pacific Advanced Network: a non-profit international consortium established on 3 June 1997. APAN is designed to be a high-performance network for research and development on advanced next-generation applications and services. APAN provides an advanced networking environment for the research and education community in the Asia-Pacific region and promotes global collaboration. For further information, see www.apan.net
APN	Access Point Name: a computer protocol that typically allows a user's computer to access the Internet using the mobile phone network.
ASPIRE	A Study on the Prospects of the Internet for Research and Education: a foresight study following on from the successful SERENATE and EARNEST studies completed in 2003 and 2008, to be completed in 2012.
AUP	Acceptable Use Policy
bit or b	Binary digit: the smallest unit of data in a computer. In this Compendium: kilobit (kb), Megabit (Mb), Gigabit (Gb).
Bandwidth on Demand	A data communication technique for providing additional capacity on a link as necessary to accommodate bursts in data traffic, a videoconference, or other special requirements.
Byte or B	8 bits. In this Compendium: MB (Megabyte), TB (Terabyte), PB (Petabyte).
CA	Certification (or Certificate) Authority
CERT	Computer Emergency Response Team: an historic term used for Computer Security Incident Response Team (see right).
CLARA	Cooperación Latino Americana de Redes Avanzadas (= Latin American Cooperation of Advanced Networks): an international organisation whose aim is to interconnect Latin America's academic computer networks. For more information, see www.redclara.net
confederation	A federation formed by multiple independent federations with a common purpose. An example in the NREN community is the European eduroam Confederation, which unites country-level eduroam federations.
congestion index	A measure of congestion at different levels of network access. Developed by Mike Norris of HEAnet.

ccTLD	Country-code Top-Level Domains: Internet Top-Level Domains (TLDs) are geographically specific and can be assigned to a dependent territory in addition to a country.
CSIRT	Computer Security Incident Response Team.
DANTE	Delivery of Advanced Network Technology to Europe: responsible for the not-for-profit organization that plans, builds and operates the pan-European and international interconnection of research and education networks.
Dark Fibre	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.
DNSBL	A DNSBL (DNS-based Blackhole List, Block List, or Blacklist) is a list of IP addresses published through the Internet Domain Name Service (DNS). DNSBLs are most often used to publish the addresses of computers or networks linked to spamming; most mail server software can be configured to reject or flag messages which have been sent from a site listed on one or more such lists.
DWDM	Dense Wavelength-Division Multiplexing: in fibre-optic communications, a technology that uses multiple wavelengths of light to multiplex signals in a single optical fibre.
E.164	The ITU recommendation that defines the international public telecommunication numbering plan used in the PSTN and some other data networks.
eduroam®	education roaming service: provides a secure international roaming service to users in the international research and education community. It allows a user visiting another institution that is connected to eduroam to log on to the WLAN using the same credentials he/she would use if he/she were at his/her home institution.
EARNEST	The Education And Research Networking Evolution Study: an activity coordinated by TERENA in the framework of the GN2 project, see www.terena.org/activities/earnest
EC	European Commission
eduGAIN	The eduGAIN service is intended to enable the trustworthy exchange of information related to identity, authentication and authorisation between the GÉANT (GN3) Partners' federations.
EU	European Union
EUGridPMA	The international organisation to coordinate the trust fabric for e-Science grid authentication in Europe.
EUMEDCONNECT2	A project to connect NRENs in the Mediterranean region to the GÉANT network.

FEIDE	National federated identity management system for the education sector in Norway, see www.feide.no
FTE	Full-Time Equivalent
GDS	Global Dialling Scheme: a hierarchy of video-conference gatekeepers that support the mapping of a telephone number format to access MCUs and VC end-points worldwide.
GÉANT	A project mainly to develop the multi-gigabit pan-European data communications network 'GÉANT', used specifically for research and education.
GN3	The Multi-Gigabit European Research and Education Network and Associated Services (GN3) project of the European Community's Seventh Framework Programme (FP7). It succeeds the GN2 project, which developed the GÉANT2 network.
Grid computing	Applying the resources of many computers in a network to a single problem.
Honeypots	A honeypot is a trap set to detect, deflect, or in some manner counteract attempts at unauthorized use of information systems. Generally it consists of a computer, data, or a network site that appears to be part of a network, but is actually isolated and monitored, and which seems to contain information or a resource of value to attackers.
Identity Management System	IdM: a system that combines technologies and policies to allow institutions to store users' personal information and keep it up to date. An IdM is the first step to providing AAI (see left) for a local or federated environment.
interfederate	Exchanging of metadata by two or more federations to allow members within different federations to connect via a federated access management exchange.
IP	Internet Protocol: the method whereby data, in the form of packets, is transmitted over a network.
IPv4	Internet Protocol version 4: the fourth iteration and first widely deployed implementation of the Internet Protocol. IPv4 supports 32-bit addressing and is the dominant Internet-layer protocol.
IPv6	The latest generation of the Internet Protocol (designated as the successor to IPv4) with 128-bit addressing as its most significant feature.
IRU	Indefeasible Right to Use: the granting of temporary ownership of a fibre-optic cable, allowing the unencumbered use of DWDM (see left) technology to maximize the capacity of the link.
Kalmar	The Kalmar e-identity Union builds an infrastructure for exchanging personal information across borders.
Lightpath	A dedicated point-to-point optical connection created through the use of wavelengths in an optical network, to provide guaranteed service levels for demanding applications bypassing the shared IP network.

MAN	Metropolitan Area Network: covers a geographical region such as a city. This term is often used interchangeably with Regional Area Network (RAN), which generally covers a wider geographic area.
MCU	Multi-point Conferencing Unit: used to interconnect multiple video-conferencing (VC) end-points. An MCU is also able to translate between different video formats, including SD (standard definition) and HD (high definition), in order to provide an optimized viewing experience for each VC unit connected.
MVNO	Mobile Virtual Network Operator: a company that provides mobile phone services but does not have its own licensed frequency allocation of radio spectrum, nor does it necessarily have all of the infrastructure required to provide mobile telephone service.
NOC	Network Operations Centre: a place from which a network is supervised, monitored, and maintained.
NORDUnet	An international collaboration between the Nordic NRENs. It interconnects these networks with the world-wide network for research and education as well as the general purpose Internet.
NREN	National Research and Education Network (can also refer to the operator of such a network).
PKI	Public Key Infrastructure: enables the use of encryption and digital signature services across a wide variety of applications.
PoP	Point of Presence: the location of an access point to the Internet.
PSTN	Public Switched Telephone Network: the traditional circuit-switched telephony service using dedicated circuits for the duration of a call.
RAN	Regional Area Network: covers a wider geographic area than a Metropolitan Area Network (MAN).
RedCLARA	Latin American advanced network, managed by CLARA.
SAML	Security Assertion Markup Language: a fundamental component of federated identity and access management systems.
SIP	Session Initiation Protocol: an IETF-defined signalling protocol widely used for controlling communication sessions such as voice and video calls over Internet Protocol (IP).
SPF	Sender Policy Framework: an email validation system designed to prevent email spam by detecting email spoofing, a common vulnerability, by verifying sender IP addresses. SPF allows administrators to specify which hosts are allowed to send mail from a given domain. Mail exchangers use the DNS to check that mail from a given domain is being sent by a host sanctioned by that domain's administrators.
TCP	Transmission Control Protocol: one of the core protocols of the Internet Protocol suite.
TCS	TERENA Certificate Service: offers a variety of digital certificates for server, personal and e-Science use at research and educational institutions served by participating National Research and Education Networks (NRENs).
UbuntuNet Alliance	A not-for-profit association of NRENs that aims to provide a research and education backbone network for Africa.
University	Institution providing an education equivalent to ISCED levels 5 and 6. 'Higher/further education' is equivalent to ISCED level 4; 'secondary education' corresponds to ISCED levels 2 and 3, and 'primary education' to ISCED level 1. For more information on ISCED levels, see www.uis.unesco.org
VoIP	Voice-over-Internet Protocol: a protocol for transmitting voice via the Internet or other packet-switched networks. VoIP is often used to refer to the actual transmission of voice (rather than the protocol implementing it). This concept is also referred to as IP telephony, Internet telephony, voice over broadband, broadband telephony, or broadband phone.
VPN	Virtual Private Network: a network that uses a public infrastructure such as the Internet to provide remote offices or individual users with secure access to their organisation's network. A virtual private network can be contrasted with an expensive system of owned or leased lines that can only be used by one organization. The goal of a VPN is to provide the organization with the same capabilities, but at a much lower cost.
X-ARF	Network Abuse Reporting Format: an email format for reporting network abuse.

« *networking the networkers* »

What is TERENA?

TERENA, the Trans-European Research and Education Networking Association, fosters the development of computer network technology, infrastructure and services for use by the research and education community. TERENA provides a forum for collaboration, innovation and knowledge sharing. The primary members of the association are National Research and Education Networking (NREN) organisations operating in countries in and around Europe. They offer advanced, high-speed, high-performance connectivity and associated services to universities, research institutions and schools on the national level.

TERENA members also include regional research networking organisations, research organisations that are major users of networking infrastructure and services, and equipment vendors and telecommunication operators.

Since the very beginning of the Internet, some four decades ago, the academic community has led the development and deployment of computer network infrastructures and technology. Although much has changed since then, the academic community remains a pioneer in networking development. In recent years, Europe has become a world leader in important aspects of research and education networking. This leading role has been made possible by cooperation and collaboration between network engineers, managers and researchers in the research and education networking community throughout the region. TERENA plays a crucial role by facilitating the coordination of policies and activities, the planning and execution of joint initiatives, and collaboration between experts working in its member organisations and the wider research networking community.

The TERENA *Compendium of National Research and Education Networks in Europe* presents abundant documentary evidence that research and education networks are at the leading edge of technological and service developments, and that Europe is at the forefront in this field of networking. The *Compendium* also highlights areas that require further work; some of that work is already being undertaken through the various TERENA activities.

The TERENA *Compendia* form a series of annual publications that began in the year 2000. They are a valuable source of information for researchers and policy makers in various countries.


GÉANT