RNP Experiences and Expectations in Future Internet Research and Development

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Abstract RNP is Brazil's NREN (National Research and Education Network), fully supported by the federal government to provide advanced network services to the higher education and research community. RNP has operated its own IP network since 1992, and has continually renewed its technology since then. This article reports on the present state of RNP production infrastructure, including expectations for 2010. Additionally, a number of different Brazilian network testbed initiatives are presented, as well as activities now being directed to Future Internet research and development.

Introduction to RNP

Electronic communication between computers reached Brazil in 1988, with the establishment of two international links to BITNET, and their extension to about 40 institutions by 1991 [Stanton 1993]. RNP was created in 1989 as a project of what is now the Brazilian Ministry of Science and Technology (MCT), to deploy a national computer network connecting universities and research centres, and provide them with access to similar networks in other countries. The first version of the RNP national backbone network was deployed in 1992 using Internet (TCP/IP) technology, connecting points of presence (PoPs) in 11 capital cities – Brasil has 26 states and a Federal District (DF) containing the national capital – and providing an international connection to the USA [Stanton 1993].

During the 1990s, RNP continued renewing and extending its network until it reached all 27 capitals. By 1999, RNP's situation had altered. Instead of being a project of MCT, with consequent instability and insecurity for RNP staff and objectives, a non-profit private company, AsRNP, was constituted by the project participants, and was subsequently contracted by MCT to manage the national network. By 2002, AsRNP had been formally recognised as a “Social Organisation” by MCT, which legally permitted the ministry to sign long-term contracts without a tender process, and to administer its relations with AsRNP in a similar way to other specialised service-providing institutions (in scientific computing, astrophysics, synchrotron light, and so on) which fell in the general category of national laboratories. Of comparable importance was the cofinancing of AsRNP activities by the Ministry of Education (MEC), which provided by far the largest contingent of clients of the national network. In addition, the network had been restructured, using the recently introduced ATM and Frame Relay technologies, which permitted incremental adjustment of available bandwidth. This new version of the network, introduced in 2000, was known as RNP2, even though it was much more limited than the Internet2 network in the US. However, it represented a significant improvement, and was what was economically feasible at that time.

The stability brought about by this reorganisation has enabled RNP to determine and follow long-term objectives, and to continue greatly to expand its network and its activities, so that it can now be considered to be a world-class research network. Much of this has come about by the continued application of new, mainly optical, technologies to providing network connectivity, by developing and deploying advanced user services, and by taking advantages of economies of scale.

RNP’s current connectivity

The current connectivity offered by RNP to its almost 600 client institutions can be described under the following categories:

- Backbone network with one PoP per capital
- Direct connections to local PoP from institutions located outside capitals
- Community-based optical metro networks in capital cities
- International connectivity

Backbone network with one PoP per capital

Ever since the first version of the RNP backbone, the design has included a single PoP in each capital, usually a federal university which distributes connectivity within the local state, or the Federal District (DF). The first version on the network used 9.6 and 64 kbps links. The current version, which is the fifth and was commissioned in 2005, uses a variety of connections, ranging from 6 Mbps to 10 Gbps (see Fig. 1).

It can be seen that the network is built around a 10 city core, including links of 2.5 and 10 Gbps, implemented as non-redundant lambdas. The remaining 17 PoPs are linked to this core by leased point-to-point circuits, varying between 6 Mbps and 622 Mbps. Connections to the two northern capitals of Boa Vista and Macapá are currently made by satellite. The remaining links are all terrestrial.

Local connections to each PoP are managed by its own staff. The institution housing the PoP has an agreement with RNP for carrying out certain operational matters on RNP's behalf.

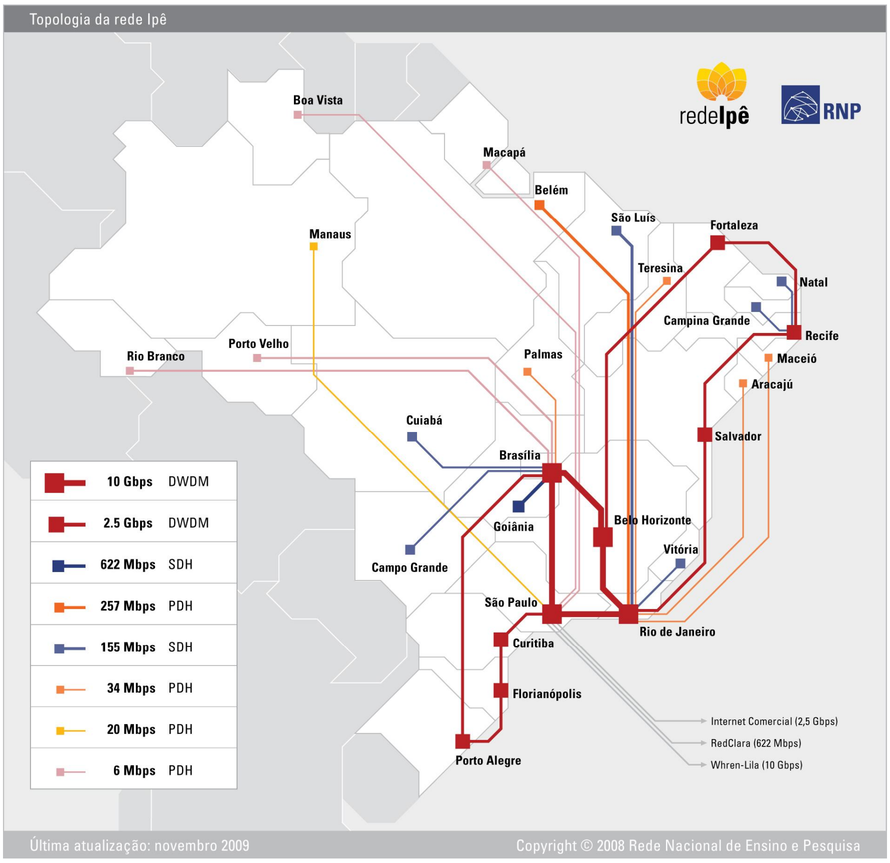

Fig. 1. Current version (v.5) of the RNP backbone network (28/11/2009) (Courtesy: RNP)

Direct connections to local PoP from institutions located outside capitals

Within each state (or the Federal District), connections between client institutions and the local PoP are handled in several ways. In some states, connectivity is provided by a statewide network, and is not an RNP responsibility. Additionally many institutions have multiple campi, of which only the main campus has traditionally been connected by RNP, it remaining the responsibility of the institution to solve its own internal connectivity problems.

In recent years, RNP has been charged with providing connectivity to the local PoP of an increasing number of federal institutions maintained by MCT and MEC, and located in non-capital cities. Most of these links are of low bandwidth (less than 4 Mbps), with the exception of federal universities and research units of MCT, which may have up to 155 Mbps connections.

Community-based optical metro networks in capital cities

RNP has been engaged in deploying its own optical fibre metro networks, initially in capital cities. This initiative was inspired by the example of the Canadian network, CANARIE, whose former chief architect, Bill St Arnaud, is a tireless proponent of community networks, where a collection of interested organisations pool their resources to build and run their own optical network. The business case for this was easy to make in Brazilian cities, due to the relatively high cost of urban links offered by telcos. It has been shown that the cost of investment could be recovered in 2 or 3 years from the savings on running costs, and the resulting capacities (minimum of 1 Gbps) were often thousands of times greater than the circuits which were being replaced.

The first such project was begun in 2004 in Belém, capital of the state of Pará. A feasibility study was carried out, and R$1.15M in funding to build the network was promised by MCT, and made available in December 2004 [Stanton 2005]. Construction began early in 2005 and the optical infrastructure was completed in mid-2006, although the network, known as MetroBel, was only inaugurated in May, 2007, after the necessary network equipment had finally been imported. The resulting network linked 32 access points belonging to 12 separate institutions, each of which had dedicated access to a pair of fibres in the entire network covering 40 km. This enabled independent access to the PoP by each institution, and the possibility of building its own inter-campus network using the common infrastructure. In many cases, the network capacity to a campus was vastly increased: the 8 separate campi of the Universidade Federal do Pará, formerly linked at 128 kbps, migrated to 1 Gbps links, a factor of 8000 times the former capacity. A map of the MetroBel network is shown below (Fig. 2).

The MetroBel project has become a model for the rest of Brazil, and before the end of 2004 MCT had asked RNP to apply this model to all other 25 state capitals and Brasília, and made a further R$40M in funding available to carry this out. This much larger project is known as Redecomep, and a further 15 capitals have already inaugurated their networks by the end of 2009. The remaining 11 are expected to do so in 2010. RNP has also been asked to build similar networks in non-capital cities throughout the country, beginning with those housing more than one federal institution maintained by MCT or MEC.

Fig. 2. The MetroBel network in Belém. The RNP PoP is located at the principal campus of UFPA, on the right side of the lower margin of the figure. (Courtesy: RNP)

International connectivity

Starting in 2001, RNP adhered to the current division of international Internet access between *collaboration*, with traffic between research and education (R&E) institutions, and *commodity*, which includes all other traffic. The global R&E Internet is accessed by dedicated international links between participating networks. RNP uses two such connections: one to the RedCLARA regional network, and a second to US networks.

The RedCLARA network was set up in 2004, largely financed by the EU through the ALICE project [Stöver 2003]. ALICE continued until 2008, establishing an interconnection of 12 national R&E networks in Latin America, with access to GEANT in Europe. The complementary WHREN-LILA project, partially funded by the International Research Network Connections (IRNC) programme of the US government agency, NSF, linked RedCLARA to US networks on the East and West coasts, starting in 2005 [WHREN-LILA 2010].

The ALICE2 project, also financed by the EU, has led to the expansion of the RedCLARA network in 2009, with the inclusion of a 13th country. In Fig. 3 it can be seen that the main regional backbone is a 622 Mbps/1 Gbps ring interconnecting São Paulo (Brazil), Santiago (Chile), Panama City (Panama) and Miami (USA), with a 622 Mbps transatlantic connection to Madrid (Spain). Most national links to this network are 155 Mbps, although significant future changes will be discussed below.

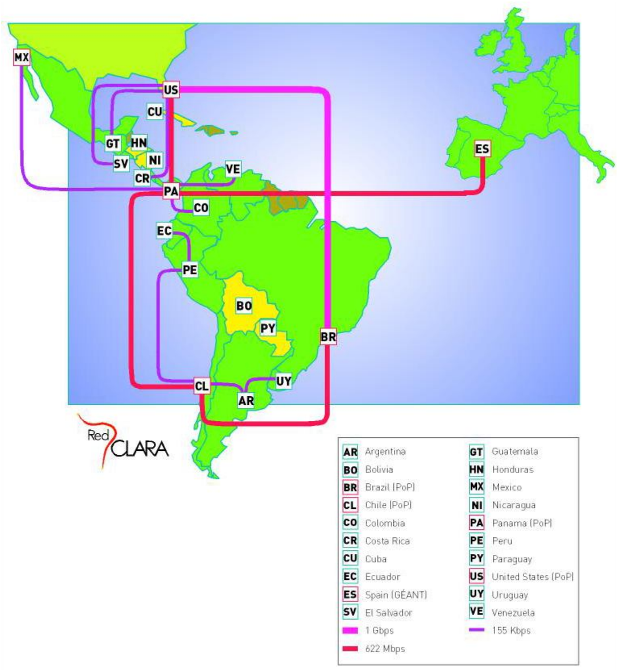

Fig. 3. RedCLARA topology in December 2009. The link shown between Brazil and the US is a subchannel of the Brazilian links to the US (see below). (Courtesy: CLARA)

A more direct impact on Brazil has been the result of altering the way RNP has dealt with international *collaboration* and *commodity* traffic to the US. By late 2008, RNP was purchasing 2 Gbps of international commodity transit in Brazil, from a large international provider, and this was insufficient. However, the price being paid was certainly sufficient to lease a 10 Gbps link between Brazil and the US, where the cost of commodity transit was not more than 25% of what was being paid in Brazil. It was decided to adopt this latter model, in which RNP was assisted by its US colleagues at the AMPATH exchange point in Miami. It should be noted that the ANSP network in São Paulo had reached a similar decision, and both networks reorganised their international links in 2009.

RNP and ANSP had been cooperating since the beginning of the NSF-supported WHREN-LILA project in 2005, of which both networks were partners in the shared use, together with RedCLARA, of a 2.5 Gbps link between São Paulo and Miami [WHREN-LILA 2009]. This cooperation became closer over the years, and has been marked by collaboration in hosting the GLIF Open Lightpath Exchange (GOLE), called SouthernLight, used for international circuit management since 2008 [SouthernLight 2010] (see later, below). The new agreement reached over the new international links was to pool (fully share) the two 10 Gbps links that the two organisations were to install between São Paulo and Miami. In addition, commodity transit in Miami would be bought from the same provider. As the two networks together already needed 3.5 Gbps of commodity transit, this was contracted in Miami for less than 10% of the price previously paid in São Paulo. The new arrangement has led to a more scalable access to commodity transit, and has effectively increased international collaboration bandwidth from 2.5 Gbps to about 15 Gbps, thus greatly increasing support for scientific collaboration.

New network infrastructure in 2010

2010 has been seen as the year that many of RNP infrastructure projects defined during the last few years would come to fruition. These included, naturally enough, the 27 optical metro networks in capital cities, expected to be operational in 2010. The metro networks were designed to complement a high-speed backbone network, also operating in Gbps. The Ipê network, as inaugurated in 2005, was seen within RNP as a major step forward, in bringing Gbps networking to 10 capital cities. However it was recognised that the next expansion would have to extend the Gbps core to many more capitals, and in 2008 a map of the expected future Ipê network in 2010 was devised, with 10 Gbps links to 18 capitals, and 1 Gbps links to the remaining 9. However, it was unclear as recently as early 2009 how this was to be accomplished.

This situation has been completely altered by the following recent development. In 2008, a takeover was mutually agreed of one Brazilian telco, Brasil Telecom, by another, Oi. However, the existing rules designed to promote competition in this sector did not allow such a combination. In spite of this, the regulatory authority, Anatel, gave its permission for the takeover, under several conditions, which included assisting RNP in its mission to connect its R&E clients for 10 years. RNP began discussing with Oi in early 2009 how this assistance could best be given, and, by early 2010, agreement had been reached for this to take the form of the provision of thirty-one optical circuits between pairs of capital cities. Of these, 11 would provide 3 GigE connections, and the remaining 20 would be fully transparent 10 Gbps lambdas. All capitals south of the River Amazon were to be included (see Fig. 4). The remaining 3 capitals will have to wait for the arrival in 2012 of electricity transmission lines from the south side of the river.

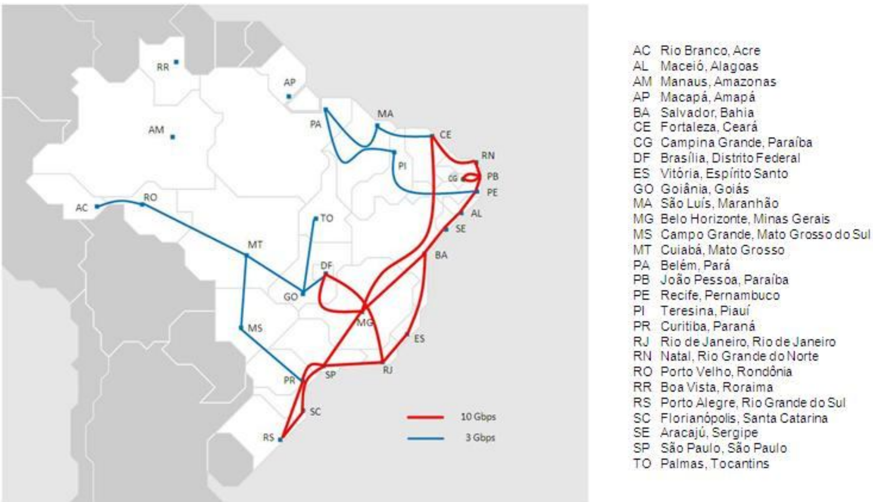

Fig. 4. Expected topology of the 10 Gbps core of the Ipê network in 2010.

The other novelty expected in RNP's network connectivity in 2010 will be due to the CLARA initiative to seek sustainable network infrastructure by establishing long-term partnerships with the owners of optical fibre assets, prepared to share them with research networks, which would then purchase the optical networking equipment which would support such joint use.

The first two such cases will provide 10 Gbps links between Chile, Argentina and Brazil in 2010. Between Argentina and Chile, a small Argentine telco agreed to cooperate with CLARA, RNP and its Argentine equivalent, InnovaRed, using a fibre pair between Santiago and Buenos Aires. The optical transmission equipment installed, which was supplied by the Brazilian company, Padtec, will make it possible to provide five 10 Gbps lambdas (optical circuits) along the entire route. A similar deal between RNP, InnovaRed and a large international telco was reached, for a fibre pair between Buenos Aires and Porto Alegre. In this case up to

8 lambdas are to be shared. In both cases, the CLARA network will gain a 10 Gbps link, and the local network (RNP or InnovaRed) will gain a further 10 Gbps for its own use, within its own country. Thus high-capacity international networking will be able to be extended from Brazil to its neighbours to the south.

Similar solutions are also being sought to provide cross-border links to Brazil from Uruguay and Paraguay.

Large-scale testbed networks in Brazil

Beginning in 2002, Brazil began to set up its own infrastructure for experimental research and development (R&D) in network technologies and distributed applications. So far there have been a number of separate initiatives.

Project GIGA Optical Testbed

Project GIGA is an ongoing project involving RNP and the CPqD Foundation in Campinas, which is the successor of the former state telecommunications monopoly´s R&D laboratories. The original partnership was brokered by MCT, and led to the joint proposal of an optical testbed network, which was funded between 2003 and 2007 by the federal National Fund for the Technological Development of Telecommunications (FUNTTEL). Using fibres lent without cost by four separate telcos, a 750 km DWDM network was established by 2004 in southeastern Brazil (states of Rio de Janeiro and São Paulo), with nodes in 7 cities and access to laboratories in around 20 universities and research centres in this region (see Fig. 5). Initially 2.5G optics were used, but later this was partially upgraded to 10G optics. Ethernet technology has been used at level 2, both 1 and 10GigE.

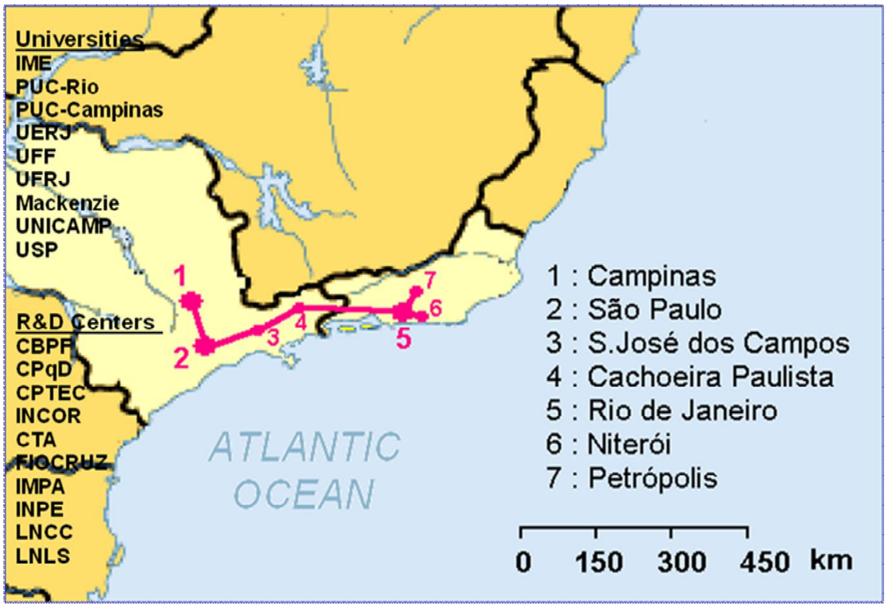

Fig.5 Geographical location of the Project GIGA optical testbed (states of RJ and SP) (Courtesy: CPqD and RNP)

All the optical transmission equipment used in this testbed has been provided by the Brazilian firm, Padtec, partially controlled by CPqD.

In addition to setting up the testbed, the funding covered the cost of extensive R&D activities, some coordinated by CPqD, in the areas of optical technologies and telecommunications applications, and the others by RNP in network protocols and distributed applications. In all, consortium-based R&D activities were carried out at more than 50 research institutions throughout Brazil, and validated on the testbed.

In addition to funded R&D activities, the testbed has also been used for providing high-capacity access to a small number of scientific groups with international collaborations, especially in grid computing and high-energy physics (HEP), in those cases when the previous connectivity proved insufficient. Thus, since 2004 the HEP group at the state university of Rio de Janeiro (UERJ), has participated in the bandwidth challenge (BWC) at the annual Supercomputing conferences in the US, using transmission facilities of the testbed between Rio de Janeiro and São Paulo.

R&D activities associated with Project GIGA activities have generated a very large number of products, including publications, of different kinds. See [Scarabucci 2005] for an early report on the project. The results of RNP-coordinated subprojects were presented at the (final) R&D Workshop for Project GIGA/RNP, held in September, 2007 [GIGA 2007].

A second round of FUNTTEL funding has been made available to CPqD for the so-called Phase 2 of Project GIGA, starting in 2009. RNP continues to collaborate with CPqD in these activities, which will be described later on in this report.

KyaTera TestbedNetwork

In 2003, the São Paulo Foundation for Research Support, FAPESP, launched the R&D programme, TIDIA (Information Technology for the Development of the Advanced Internet), of which one of the component projects was an optical testbed network, called KyaTera, which has been operating since 2007. This testbed links together research laboratories in institutions in 9 cities, using similar network technology to Project GIGA (Ethernet/WDM), and provides them with access to international connectivity in the city of São Paulo. Further information about this network, including maps, can be found at [KyaTera 2010].

Again the research activities are mixed, with emphasis on optical technologies and distributed applications.

PlanetLab

The first PlanetLab [Peterson 2003] node in Brazil was created in Belo Horizonte in 2003, by a former student of Professor Larry Peterson of Princeton University. The following year, with a donation from the Intel Corporation, RNP deployed a further 3 nodes, and began to administer them on behalf of the networking research community in Brazil. Further interest in this facility has been generated over the years through occasional visits of PlanetLab specialists to the country, most recently from the European OneLab project in 2009.

GLIF – Global Lambda Integrated Facility

GLIF has worked steadily since 2003 to disseminate the adoption of hybrid packet-circuit networks, with the use of end-to-end circuits for high-volume flows – an early rationale for this was provided in [de Laat 2003]. After gaining initial experience with such circuits in October 2007 for transmitting standard definition (SD) and compressed high definition (HD) video streams between Rio de Janeiro and Barcelona as part of the ArtFutura event, RNP, accompanied by its partners, ANSP and CPqD, joined the GLIF community in 2008, registering the SouthernLight GOLE, the Ipê network and the GIGA and KyaTera testbeds as usable GLIF resources. These appear on GLIF maps made available in that year [GLIF 2009].

GLIF community resources were used extensively in the inauguration of the first of the two 10Gbps links in July, 2009, with the worldwide première of the full length Brazilian feature film, Quando a Noite Chega (When Night Falls), made using 4K digital technology and simultaneously exhibited locally in São Paulo, and remotely at UCSD in San Diego (US) and at Keio University in Yokohama (Japan), to which the film was transmitted in compressed form (400 Mbps). The event also featured uncompressed HD videoconferencing with Keio University (900 Mbps). In the aftermath of this event, RNP accepted the invitation to become a network member of the CineGrid community [CineGrid 2009].

Dynamic Circuit Provisioning

The GLIF community has been investigating dynamic provisioning of end-to-end circuits for several years, as a means of automating the hitherto manual process of setting up the circuits. Based on work carried out from 2005 in the DRAGON testbed at MAX [Lehman 2006] and the On-demand Secure Circuits and Advance Reservation System (OSCARS) system since 2004 at ESnet [Guok 2006], Internet2 and ESnet jointly deployed a pre-production dynamic circuit (DC) network in 2007 [Lehman 2007]. It was thus demonstrated that what had previously required long setup times for circuits crossing multiple domains could now be performed in a matter of minutes, greatly reducing the operating costs and increasing the utility of this network service.

This demonstration has given new life to the GLIF activities, leading to the fusion of the previous Technical and Control Plane working groups, which had formerly been seen, respectively, as the present and future faces of GLIF. In addition, GLIF community influence is also visible in the effort that has recently been invested in standardisation of end-to-end circuits within the Open Grid Forum (OGF), through the working groups on Network Service Interface (NSI) and Network Markup Language (NML) [OGF-NSI 2008].

RNP's future backbone network in 2010 is also intended to adopt a hybrid packet-circuit architecture, and work is underway since 2008 on the design and implementation of a dynamic circuit capability, which will be able to interoperate internationally with other research networks. This project, known as FuturaRNP, is investigating a number of technical alternatives, such as DRAGON/OSCARS, UCLP/ARGIA [UCLP 2010] and AutoBAHN [GEANT2 2010], with the participation of research groups from 10 institutions, including CPqD.

The FuturaRNP project includes a testbed for development, which we call the Creeper Network (Rede Cipó), implemented as a Virtual Private LAN Service (VPLS) interconnecting the dedicated level 2 (Ethernet) networks at each institution [RedeCipó 2009]. These single domain networks are similar to the "pods" used by Internet2/MAX for carrying out training in DC technology at Internet2 events [I2-DC-workshop 2008]. By mid-2010 it is hoped to be able to migrate the resulting solution to the new Ipê network to be deployed around that time.

Experimental Future Internet R&D

RNP continues to partner CPqD in Phase 2 of Project GIGA, which is, by agreement, concentrating its activities on R&D in "Future Internet" architectures and applications. In addition to the original testbed in southeast Brazil described above, it is expected that the geographical coverage of the Phase 2 testbed will be extended to coincide with the greatly expanded 10Gbps core of the future Ipê network.

Large-scale Future Internet testbeds are beginning to be deployed in North America, the EU, Japan and Korea. In the USA, NSF launched its GENI (Global Environment for Network Innovations) programme in 2005 and, after several years spent on design, began in 2008 to formulate and deploy an experimental facility to support R&D into new network architectures [GENI 2009]. The EU launched its FIRE (Future Internet Research and Experimentation) programme, also in 2008, based initially on a number of existing testbed projects: OneLab, Panlab, FEDERICA and Phosphorus [FIRE 2009]. Meanwhile, in Japan the AKARI project was launched to design a New Internet by 2015 [AKARI 2008].

There are ostensibly several similarities between these different proposals, especially in the technologies adopted. In principle, all these testbeds seek to support simultaneous use by concurrent projects (architectures). To carry this out, extensive virtualisation is carried out, both of network resources, including switches, and of processing and storage devices available on the network. This latter facility was originally included as a fundamental part of PlanetLab technology, and this has now been extended into network virtualization by variants of PlanetLab, such as VINI, which enable the virtualization of a level 3 router based on a PC [Bavier 2006]

The most general model is that of GENI, which supposes the existence of a level 2 transport service linking network nodes containing programmable and virtualisable routers, as well as processing and storage elements. Among the programmable routers, apart from the VINI model, are such designs as OpenFlow (OF) and NetFPGA [McKeown 2008]. On the other hand, the FEDERICA project has adopted the use of production IP routers which support router virtualization [FEDERICA 2009].

One thing is quite clear: there is considerable interest in interoperation of these different testbeds, leading to collaboration around the globe. In Brazil, several invitations have been received to participate in testbed projects which were proposed to GENI in 2009. Therefore, in the planning of a Brazilian Future Internet experimental facility, future interoperation with foreign partners is of great importance.

It should be mentioned that a couple of Brazilian Future Internet R&D projects are already underway: Horizon and WebScience

Horizon is a project to study new Internet architectures, which is being jointly carried out by a consortium of French and Brazilian universities, together with industrial partners, and funded by their respective governments [Horizon 2010].

Web Science is a large consortium of more than 100 researchers from several leading universities, which is being funded for 3 to 5 years of research activity by CNPq, under its National Institutes of Science and Technology programme [WebScience 2010]. RNP and a group of researchers from 5 universities have included in this project the establishment of a VINI-style testbed for experimental research into Future Internet architectures.

Lastly, interest has been expressed at government level in coordinating officially funded projects in the Future Internet area between Brazil and the EU, with a first call expected to be published in 2010.

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