Building Optical Networks for the Higher Education and Research Community in Brazil

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Abstract— The Brazilian National Research and Education Network - RNP - is currently engaged in a nationwide program to upgrade the capacity of the communications networks used by the Education and Research institutions in the country. An essential component of this program is the deployment of metropolitan optical networks in the major population centers. The article describes the background to this initiative, the methodology adopted and the expected results.

Keywords—Metropolitan area networks, Optical fiber communication.

I. INTRODUCTION

The Brazilian national research and education networking (NREN) initiative dates from 1987, when a meeting was held at the University of São Paulo which brought together for the first time university researchers from all parts of the country, government grant agencies, the then telecommunications monopoly and the special state secretariat for informatics [1]. As a direct result of this meeting, a coordinated plan emerged, firstly to establish national and international connectivity as from 1988 using BITNET technology [2], later migrating in 1991-2 to Internet technology [3].

Brazil has a federal constitutional order, similar to the USA, with 26 states and a Federal District around the national capital, Brasília. Internet technology was introduced to Brazil by a concerted action involving initiatives due to state governments in a number of the more populous states, such as São Paulo, Rio de Janeiro and Rio Grande do Sul, and a national initiative maintained by the federal government and known initially as the National Research Network (RNP - Rede Nacional de Pesquisa) [4]. RNP began in 1989 as a project of the National Council for Scientific and Technological Development (CNPq), and had as its main objective the establishment of national and international connectivity for the nascent state initiatives.

The first national IP backbone network in Brazil was launched by RNP in 1992 to serve the national academic and research community, and connected 11 cities at transmission rates of 9.6 and 64 kbps [1]. Since 1992, the national network run by RNP has evolved through three significant increases in capacity and usually also technology and is about to make a fourth such change by the fourth quarter of 2005. Table I summarizes these changes.

<table>
<thead>
<tr>
<th>Year</th>
<th>Technology</th>
<th>Link capacities</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>BITNET</td>
<td>up to 9.6 kbps</td>
<td>first national network</td>
</tr>
<tr>
<td>1992</td>
<td>Internet</td>
<td>9.6 and 64 kbps</td>
<td>first IP network (RNP)</td>
</tr>
<tr>
<td>1995</td>
<td>up to 2 Mbps</td>
<td>also: commercial IP deployed in Brazil</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>IP/ATM, IP/FR</td>
<td>VC up to 45 Mbps, access up to 155 Mbps</td>
<td>RNP2 national network; testbed metro networks in 14 cities (using ATM)</td>
</tr>
<tr>
<td>2003</td>
<td>IP/SDH</td>
<td>34, 155, 622 Mbps</td>
<td>also: IP/WDM interstate testbed network (GIGA)</td>
</tr>
<tr>
<td>2005</td>
<td>IP/WDM</td>
<td>2.5 and 10 Gbps</td>
<td>RNPng; metro networks in 27 capitals</td>
</tr>
</tbody>
</table>

The objective of this article is to describe this latest stage in the evolution of the Brazilian academic networking infrastructure, giving particular emphasis to the use of optical technology and pointing out the importance of previous experience with testbed networks both at the metropolitan and long-distance levels.

II. BRAZILIAN REACTION TO INTERNET2

The Internet2 initiative in the USA was launched in 1996, presenting a compelling vision of the capabilities of advanced networking and the promise of bringing these soon to the research and education community. Over the last ten years the power of this vision has revolutionized the way in which communication is used in this community, and that there now is a vibrant and global research and education networking infrastructure is the consequence of the impact of example on other countries throughout the world.
This is also true in Latin America and particularly Brazil. The Internet2 initiative in the USA coincided with the launch of commercial IP networking in Brazil, in which RNP played a significant role, due in no small part to the experience gained during the previous three years of operating the only national IP network in the country. However, it became clear that RNP's role would best be confined to the phase of kick-starting commercial IP networking, after which it should return to providing support only for research and education networking.

In Brazil in particular, this was an unusual moment as the federal government was engaged in reforming the telecommunications sector, ending the state monopoly and replacing it with regulated competition. Between 1997 and 1998 all the state-owned telecommunications operating companies (telcos) were regrouped and privatized through public auction, and new companies licensed to compete with the newly privatized former monopoly telcos.

It was during this period of the late 1990s that a strategic plan was adopted by RNP to pursue the separate development of the networking infrastructure for the research and education community, which would follow the Internet2 road of providing support for those advanced applications that could not be used on the existing commodity IP networks due to lack of capacity or poor performance. This led to two important initiatives: the introduction of the RNP2 national network in 1999, and the creation of 14 metropolitan area testbed networks between 1998 and 2000.

Although the previous phase of the national network had by now reached the capitals of all 26 states, in addition to the national capital, the RNP2 network was the first network planned from the beginning to provide access to the whole country. This was based on the use of ATM and Frame Relay (FR) communications services provided by the then state monopoly long-distance telco. In general, the more densely populated eastern side of the country was served by ATM, whereas FR was used in the less-populated remainder, especially the Center-West and the North. In general RNP2 provided scalable and reliable IP service to the user community, with point-to-point links (virtual channels) on the ATM part of the network reaching as much as 45 Mbps. Fig. 1 shows the situation of RNP2 in 2001.

Although the name RNP2 was inspired by Internet2, the capacity offered to the users was insufficient for the advanced applications which were available in the latter network, due to bandwidth restrictions. At that time it probably not have been financially feasible to provide a general network with such high capacity. However, in 1999 such network services as 155 Mbps point-to-point links were simply not amongst those offered by telcos to their clients.

The metropolitan area testbed networks, known as ReMAVs from the Portuguese name for "metropolitan high-speed networks", were RNP's response to this situation. These were the first facilities-based networks used by the Brazilian research and education community, and were based on dark fiber, usually provided by the then monopoly telcos, lit up with ATM switching equipment supplied by IBM. CNPq also provided grant support for development activities during two years. A ReMAV typically would connect R&D laboratories in up to a dozen institutions in the same city, and provided for the first time realistic conditions to develop and demonstrate the use of advanced applications between the members of this metropolitan consortium. Fourteen ReMAVs were deployed starting in 1998, and further information about them may be obtained from [5].

Finally, the RNP organization itself began to change, moving from the original grant-supported project to adopting the more permanent structure of a non-profit company with regular employees and a long-term contract with the Ministry of Science and Technology to manage and develop the national research and education network [6]. During this period the name of the organization was altered to include "education" as well as "research", although the initials "RNP" remained unaltered.

III. PROJECT GIGA AND THE TIDIA PROGRAM

As mentioned above, the RNP2 network was widely perceived, especially within the Brazilian academic networking community, as being only a partial response to the challenge provided by Internet2. The ReMAVs were obviously a step in the right direction, but what was lacking was the long-distance interconnection of the metropolitan testbeds at suitable capacities to permit the end-to-end use of advanced applications between different cities, and even with correspondents in other countries.

To discuss what to do next, a workshop on the next generation RNP network (RNPng) was organized at RNP's Rio de Janeiro headquarters in April, 2001, with the participation of researchers in networking and in important end-application areas such as high-energy physics, health and bioinformatics, as well of a representative from the high-performance computing community, the directorate of RNP and the responsible official in the Ministry of Science and Technology.
At this meeting the end-users provided their vision of what was needed for national and international collaboration. Presentations were also made of recent networking developments in other countries, such as CAnet3 in Canada [7] and Gigaport in the Netherlands [8]. An important voice was that of the representative from CPqD (the R&D center of the then former telecommunications monopoly), who described the intention of his organization to build an intercity optical networking testbed within São Paulo State to support both hardware and application development.

This initiative at CPqD has had extensive consequences. As a direct result, CPqD and RNP proceeded to form a partnership to build this testbed network, which was extended to include cities in the neighboring state of Rio de Janeiro. This Project GIGA has been supported financially since December, 2002, by the federal government's Fund for the Development of Telecommunications Technology (FUNTTEL) and has resulted in building a 700 km network, using dark fiber provided by four telcos, lit up using WDM optical equipment provided by the Brazilian company Padtec, a spin-off of CPqD, which provides IP service over Gigabit Ethernet to end users in 17 research institutions and 4 telcos in seven cities (see Fig. 2). Most users are R&D groups developing subprojects of Project GIGA, under contract to CPqD or RNP. For a fuller description of Project GIGA see [9].

The other major consequence of the original CPqD initiative is the TIDIA Program (Information Technology in the Development of the Advanced Internet), supported by the state agency, FAPESP, in São Paulo, which has similar objectives to Project GIGA, including the building of an extensive intercity IP over optical network for R&D use, and the financial support of R&D activities in networking and distance learning, and of activities related to technology transfer [10].

The final product of the RNPng workshop in 2001 was the formulation that year of a long-term strategy by RNP, thenceforth known as the National Optical Initiative (ION), which would place the emphasis on providing future network services to end-users through a "facilities-based" infrastructure, such as dark fiber or WDM waves, rather than one based on renting telco-provided services, like ATM or SDH. The networks built by Project GIGA and the TIDIA program are good examples of this new approach to building advanced networks.

IV. RNPNG - THE NEXT GENERATION OF THE RNP NETWORK

The testbed networks supported by Project GIGA and the TIDIA Program are providing extensive hands-on experience in the design, deployment and operation of both metropolitan and long-distance optical networks, and thus a base for future development of networks provided to serve the wider research and higher education community. Within RNP, forward network planning has been heavily influenced by the experience gained in Project GIGA, particularly related to identifying and serving particular user groups, and also as regards the technologies to be employed.

Evidently, we have also had to be attentive to new directions in networking adopted in other countries during the last five years, highlighted by such initiatives as National Lambda Rail [11], CAnet4 [12] and SURFnet6 [13], amongst others, and widely reviewed in the excellent series of reports produced by the European SERENATE study [14].

Early on, it was decided that RNP should join the global tendency to increase the link capacities of its national network to multiple Gbps. This is in fact being undertaken by the end of 2005, but has been preceded by a migration to SDH links starting in 2003, with the abandonment of ATM and FR as link technologies (see Fig. 3). The fact that this could be achieved with an increase in aggregate link bandwidth of around 6 times (from 350 Mbps to over 2 Gbps) with a 30% reduction in cost is a reflection of combination of newer technologies and the introduction of competition in the telecommunications marketplace.

In 2005, RNP moved onto the next stage of its development plan, replacing the links between the 10 principal cities of its national network by seeking a solution in the form of unprotected transparent lambdas (waves) of 2.5 and 10 Gbps (see Fig. 4). This tender process was
discussed in the remainder of this paper.

problem is the metropolitan optical network, which will be to the task. The solution which is being applied to this access networks, which have formerly usually been adequate network, as all of a sudden the bottleneck has moved to the core will ever be congested in the foreseeable future. In fact, bandwidth of almost 180 times.

The increase in aggregate link bandwidth for this new network core is from around 1.6 Gbps (SDH) to 60 Gbps (waves), or almost 40 times, at only 3 times the cost! In fact, the overall cost of the whole national network is now just 30% more than in 2003, for an increase in aggregate bandwidth of almost 180 times.

With this alteration, there is now no way that the network core will ever be congested in the foreseeable future. In fact, we now have the opposite problem of how to fill this network, as all of a sudden the bottleneck has moved to the access networks, which have formerly usually been adequate to the task. The solution which is being applied to this problem is the metropolitan optical network, which will be discussed in the remainder of this paper.

V. EXISTING METROPOLITAN OPTICAL NETWORKS

Metropolitan optical networks have been deployed for testbed use in the ReMAVs of 1998 and in Project GIGA in 2004, as well as in a number of specific projects used for more general purpose research and education networks, such as the internal network of the Universidade Federal Fluminense (UFF) or the ReMAVs established in the cities of Curitiba, Porto Alegre, Rio de Janeiro and Salvador.

A. The prototypical ReMAVs

These have been described above in Section II, and were generally based on dark fibers provided without cost by the local telco, subject to the restriction that these fibers could only be used for testbed purposes. The fiber was lit up using ATM switches from IBM, and typical transmission rates were 155 Mbps.

B. ReMAVs of Rio de Janeiro, Curitiba, Porto Alegre and Salvador

In Rio de Janeiro, the network was set up in 1998 using dark fiber provided by the local telco, lit up by 3Com ATM switches deployed with funding provided by the state agency FAPERJ. Since that time, this ReMAV has formed the core of the Rio de Janeiro State research and education network, Rede Rio, with a 155 Mbps five-node ring, whilst other institutions are attached by a point-to-point connection to one of these five ring nodes. In 2005, the technology of the core ring was upgraded from ATM to Gigabit Ethernet. See [15].

The ReMAVs in Curitiba, Porto Alegre and Salvador are similar to the prototypes established from 1998 onwards, with the difference that the dark fiber belongs to the consortium institutions instead of to the telco, and so there are no restrictions on the use to which it can be put. Thus, these two ReMAVs, like the one in Rio de Janeiro, are used for access to the RNP national network and for commodity and international connectivity. Starting in 2002, the original ATM technology is gradually being replaced by Gigabit Ethernet on the core links of these three networks.

C. The internal network of UFF [16]

The case of UFF is particularly important as it is an example of a custom-built metro network. Located in Niterói, in Rio de Janeiro State, UFF has in common with many other urban universities the fact that it occupies several different campi within a single city. Before 1998, voice and data services between these campi were provided by the local monopoly telco at high cost and low capacity. The deployment in 1997 of a new wireless access link to the RNP point of presence (PoP) in the neighboring city of Rio de Janeiro obliged the university to upgrade its internal communications infrastructure, and this was accomplished by building in 1998 its own dark fiber infrastructure, initially connecting about 50 buildings in twelve separate campi. The campi were interconnected using a total of 12 km of aerial fiber optic cable, installed using the utility poles of the local electrical power company, whilst campus cables were installed on utility poles or in ducts.

As the infrastructure was purpose-built, it was possible to select the cable type and the number and quality of strands to meet user needs, both present and expected. 18-strand cables were used, with a combination of 12 single mode and 6 multimode strands on intercampus links and 6 single mode and 12 multimode strands within the campi. The link technology deployed in 1998 was 622 and 155 Mbps ATM on the intercampus core network and Fast Ethernet for on-campus access links. The original ATM equipment was supplied by IBM, and is being replaced in 2005 by Gigabit Ethernet supplied by D-Link.

Although the UFF network is only used by a single client, it possesses many of the characteristics of a metropolitan area network, due to the large number of different campi served. As we shall see below, the UFF network has served as model for a whole new family of metropolitan optical networks currently under construction.
D. The metro networks of Project GIGA

The networking testbed of Project GIGA connects 22 points in 7 cities, including the two megacities of Rio de Janeiro and São Paulo and the large city of Campinas [9]. In all three of these cities, access is provided using dark fibers in the metropolitan fiber plant of the local telcos. Unlike in the UFF network, Project GIGA makes use of existing telco fiber infrastructure which has to meet other requirements. In order to economize the number of strands used, coarse wave division multiplexing (CWDM) has been deployed on many of the routes, using equipment provided by the Brazilian company, Padtec.

As in the prototypical ReMAVs, use of the fiber provided without cost by the telcos for Project GIGA is generally restricted to testbed and demonstration purposes.

VI. METROBEL: A PILOT PROJECT FOR ACADEMIC COMMUNITY METRO NETWORKS

In 2004, RNP carried out a feasibility study of installing an optical metro network to serve 12 public and private research and higher education institutions located in the metropolitan area of Belém, capital of Pará State in northern Brazil [17]. The plan for this network was to use a common, shared optical infrastructure to meet the following three objectives:

- integration of multicampus institutions by use of a single internal network;
- interconnection between the different participating institutions;
- provision of access to the PoP of the RNP national network, located at the main campus of the Universidade Federal do Pará (UFPA).

It should be noted that half the institutions contemplated in the feasibility study possess multiple campi. Naturally, these institutions already independently use solutions to their problems of both intercampus connectivity and Internet access, usually by renting point-to-point urban links from one of the local telcos. In general, these links are of very low capacity and rather expensive. Some real examples include (using the exchange rate US$ 1 = R$ 2.50):

- 256 kbps for US$ 8,000 per annum
- 1 Mbps for US$ 17,000 per annum

In 2004 the 12 institutions contemplated in the study spent between them over US$ 260,000 annually for very low capacity, sometimes as little as 128 kbps for an intercampus link.

The proposed alternative solution resembles the project for the UFF network, using aerial fiber optic cable in a ring topology, in order to provide robust links between the different campi of each institution. The key to lowered costs is to share the same optical infrastructure for all of the institutions in the project. In the case of Belém, it is estimated that about 40 km of cable will be sufficient to touch all of the 30 campi included in the proposed network.

The local electrical power company has agreed to permit use of their utility poles for the fiber optic cable, and is in fact interested in using a pair of strands in the installed cable for its own purposes. The total construction costs will be around US$ 360,000, assuming around US$ 9,000 per km. For each institution the share in the construction cost, if spread equally, corresponds to just 3.3 km, or around US$ 30,000.

Separation between the internal networks of the different institutions is implemented by dedicating a different strand-pair to each institution. Thus, each multicampus institution will have access to a dedicated pair of strands in the complete ring, which may be used for internal communication. Access to the RNP PoP is simple. The cable passes through the PoP, which is one of the campi of UFPA. To enable access to the RNP national network, each institutional strand-pair will also connect to the PoP.

Topologically, the resulting network is a set of separate institutional rings joined together at the PoP, that is, a star of rings (see Fig. 5a). An alternative topology, a ring of rings, provides interconnection of separate institutions and to the RNP PoP using an additional ring to which one site in each institution is connected (see Fig 5b). The star of rings was first suggested in the MetroBel project. The alternative ring of rings was first advocated in the similar REPAM project in Manaus (see below). A comparative study of these two alternatives has been carried out recently by RNP [18].

This choice of topology determines the type of equipment needed. Today's link technology of choice is Gigabit Ethernet, for reasons of price/performance. In principle, each institution will require a two optical port switch for attachment of each campus to the ring. With a star of rings topology, the PoP will require a larger capacity switch, with a pair of optical ports for each institutional ring. The ring of rings topology requires a smaller switch at the PoP. We estimate that the equipment costs for connecting 30 campi in this manner will not exceed US$ 240,000, giving total investment costs of US$ 600,000.

The annual cost of running this network have been estimated at around US$ 70,000, which corresponds to almost US$ 6,000 per participating institution. This includes operations staff, cable maintenance and rental of the utility poles.

Figure 5. Two alternative topologies

(a) Star of rings (b) Ring of rings
We thus see that the investment costs of US$ 600,000 correspond to about two years and 4 months of current telco rental fees for this set of institutions, and that the total (investment + operating) cost of a 1 Gbps urban link using the new infrastructure over a five year period is a little over US$ 6,000 per annum, which is somewhat less than the present cost of a 256 kbps link, for 4,000 times the bandwidth.

In another paper presented at this event, further details are given about the metro network project for Belém, as well as a study comparing this solution with another based on WiMax technology [19].

VII. A NATIONAL PROGRAM OF METRO NETWORKS FOR THE RESEARCH AND EDUCATION COMMUNITY

The Brazilian Ministry of Science and Technology (MCT) decided in August, 2004, to make a one-year grant of around US$ 450,000 to cover most of the investment costs of the MetroBel project. This contribution will be supplemented by direct investment by the three private universities taking part in the project. RNP is coordinating this project, in partnership with UFPA, and the metro network is expected to be commissioned by the end of 2005.

In December, 2004, MCT announced a two-year grant of around US$ 16,000,000 to support the Redecomep (Community Networks for Research and Education) project. This project, also coordinated by RNP, extends the approach being used to deploy an optical metro network in Belém to the federal capital, Brasília, and to the other 25 cities throughout the country, which are the sites of PoPs of the RNP national network, all but one of which are state capitals. (In Paraíba State, the RNP PoP is in Campina Grande, rather than in the state capital of João Pessoa.)

Because of the sheer scale and strategic importance to RNP of this second project, a special task force has been created to manage it, under the leadership of the second author. Whereas the design of MetroBel had been discussed for more than a year, the two-year time constraint of Redecomep requires a much more expeditious handling of the 26 metro network projects. In all these cases, it is vital quickly to identify the participating institutions and available local resources, so as not to waste precious time and the opportunity to include as many institutions and camps as possible in the metro networks.

Fortunately, the fairly recent experience of deploying the ReMAVs starting in 1998 means that there are many potential collaborators in the research and education institutions who already have previous experience in the deployment of metro networks. As has already been mentioned, several of these ReMAVs are still operational, and those in Curitiba, Porto Alegre, Rio de Janeiro and Salvador have already achieved the status of general access networks for the local academic community. In other cities, especially in Fortaleza, Natal and Florianópolis, the earlier experience with ReMAVs has led to institutional involvement with successor schemes, some of which have already reached the stage of deployment. Finally, in Manaus, which had been unsuccessful in its attempts to deploy a ReMAV in the late 1990s, a local initiative had already secured significant funding from the Amazonas State government for construction of a metro network. This partnership between state (local) and RNP (national) interests is clearly benign, as the result is increased investment and a larger coverage of the resulting network.

It is clearly impracticable to deploy all 26 new metro networks simultaneously, and so priority is being given in 2005 to those cities where planning is already advanced, and also to those which house PoPs of the network core of RNPng, which is to be commissioned in October of this year (see Section IV).

Apart from identifying potential candidate institutions and available local resources, the project methodology includes a series of steps carried out over a twelve month period and enumerated in Table II.

Evidently, these steps need to be repeated for each individual metro network. Equally evidently, the repetitiousness of the process permits the wholesale treatment of many aspects of the separate projects. These include:

- the development of model management structures to use in the different networks, with a common form of memorandum of understanding (MoU), which can easily be adapted to specific situations;
- a report presenting and comparing several standard models for network architecture, including the star of rings of the MetroBel project and the ring of rings of the REPAM project in Manaus [18];
- standard tender documents for both building the fiber optic cable infrastructure and acquiring the switches.

In addition a website for the project has been created both for describing and divulging the project and for documenting its progress [20]. Within the Redecomep project, the private area of the website also doubles as a tool for project management.

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Project management planning</td>
</tr>
<tr>
<td>2</td>
<td>Appointment of manager and steering committee</td>
</tr>
<tr>
<td>3</td>
<td>Appointment of technical committee</td>
</tr>
<tr>
<td>4</td>
<td>Specification of physical and logical network project</td>
</tr>
<tr>
<td>5</td>
<td>Signature of Memoranda of Understanding</td>
</tr>
<tr>
<td>6</td>
<td>Tender for equipment and network construction</td>
</tr>
<tr>
<td>7</td>
<td>Acceptance of equipment</td>
</tr>
<tr>
<td>8</td>
<td>Deployment of physical network (fiber optic cable)</td>
</tr>
<tr>
<td>9</td>
<td>Deployment of logical network (equipment)</td>
</tr>
<tr>
<td>10</td>
<td>Planning of network maintenance and operations</td>
</tr>
<tr>
<td>11</td>
<td>Commissioning of network maintenance and operations</td>
</tr>
</tbody>
</table>

Lastly, it is important to emphasize that amongst the target cities for this project are the megacities of Rio de Janeiro and São Paulo, respectively with populations of around 10 and 20 million. Whereas in most other capitals the
interested institutions can be reached with a relatively modest network of 30 or 40 km in extension, this is unlikely to be sufficient in these metropolitan areas, because of their sheer size. In these two cases, it will be necessary to find creative solutions in order to meet the projects objectives.

Fortunately, these cities also can count of parallel initiatives maintained by the respective state governments. We have already mentioned the Rede Rio in Rio de Janeiro, which was deployed in 1998 and whose network core has recently been upgraded from 155 Mbps ATM to Gigabit Ethernet. This network core reaches 5 nodes within the city, and it seems probable that agreement can be reached with the state government to develop jointly a larger metro network common solution incorporating the existing network core of Rede Rio.

In São Paulo, the TIDIA program [10] has extensive optical fiber assets both in the capital and beyond, and the state academic network ANSP [21] also maintains significant optical infrastructure in the capital region. Initial contacts indicate that a mutually acceptable solution for solving common problems can be worked out.

VIII. CONCLUSION

With the deployment of the RNP ng network core and the first wave of optical metro networks expected by the end of 2005, RNP is bringing about a significant change in the quantity and quality of communications resources at the disposal of the Brazilian research and higher education community, permitting the widespread use of advanced applications.

Future efforts will be directed towards extending more widely these facilities, bringing multiple gigabit connectivity to the remaining seventeen state capitals and also to population centers outside the metropolitan districts of the national and state capitals.

We should like to conclude by calling attention to what we consider to be an important and enduring feature of RNP's activities in seeking to provide up-to-date communications resources for the clients in the higher education and research community: that of extending the frontier of what the telecommunications sector provides to its clients. On several occasions, in order to provide advanced services to this community, RNP has procured from the telcos services which were not then on offer commercially.

This was the case in 1992, when the first 64 kbps connections were requested, and also in 2005, when unprotected waves were the technology of RNP's choice. On both occasions, the telcos reacted positively to meet RNP procurements, and invested in new technologies in order to provide the services tendered to RNP. This has led to the strengthening of local industry, which has been able to supply the telecommunications equipment needed by the telcos, and also to a significant upgrade of the generally offered telco services.

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