

# Use of Subfluvial Optical Cable in a Region Without Land-Based Infrastructure – a Project to Deploy Advanced Communications in the Amazon Region

Eduardo GRIZENDI†, Michael STANTON‡

*RNP - Rede Nacional de Ensino e Pesquisa, Rua Lauro Müller, 116, 11th floor,  
Botafogo, 22290-906, Rio de Janeiro, RJ, Brazil  
Tel: + 55-21-2102.9660, Fax: + 55-21-2279-3731.*

*† on secondment from Instituto Nacional de Telecomunicações – Inatel*

*‡ on secondment from Computing Institute, Universidade Federal Fluminense - UFF  
Emails: [eduardo.grizendi@rnp.br](mailto:eduardo.grizendi@rnp.br), [michael@rnp.br](mailto:michael@rnp.br)*

## Abstract

For several years, terrestrial optical cable has been deployed along highways, railways and electric power transmission lines. These land routes have been used to support national and regional backbones of telecommunications networks, in particular, Internet backbones. To complement these, there is massive use of submarine optical cables for intercontinental connection of national telecommunications networks, giving them worldwide reach.

However, in many countries, there are still regions where no such land routes exist, notably in areas of difficult access by land and of low population density. Some of these regions have, in the rivers that traverse them, a common solution to meet diverse society needs. One of them is the Amazon region of Northern Brazil and some neighbouring countries, where there are few roads serving the main cities and where the population lives mainly along the banks of the great rivers that cross it.

This paper aims to highlight the alternative of deployment of optical routes along riverbeds in regions where there are few or no roads, railways or even electric power transmission lines, and to present a Brazilian project, still in its early stages, of the deployment of a set of optical cables along the courses of its major rivers - the Amazon, Negro and Solimões. It is hoped that this approach may serve as an example for large river basins in other continents with difficult land-based access.

## Keywords

Subfluvial optical cable; Amazon region; Brazilian Broadband Plan; alternative of deployment of optical routes in Amazon region

## 1. An Overview of the RNP network

This section provides an update to a more extensive but earlier description of RNP, presented at UbuntuNet-Connect 2012 [Grizendi 2012].

RNP, which was created as a project in September 1989 by the Ministry of Science, Technology and Innovation (MCTI), and which became a non-profit company in 1999, operates the Brazilian national research and education network (NREN), the principal research and education (R&E) network provider in the country, serving more than 300 organisations nationwide, including over 130 public universities and 30 public and private research centres. As many of these have multiple campi in different cities, the total number of connected sites is more than 800.

In this section, we deal first with RNP's international connections, and then concentrate on access to client campi. This will then lead to a discussion on non-conventional access to remote areas of Brazil.

### 1.1 RNP international connections

RNP's international connections are provided by two separate solutions. In one of these, RNP, currently shares with ANSP, the academic network from São Paulo state, four 10 Gb/s links from the city of São Paulo to Miami in the US, which are managed jointly (see Figure 1). These four links carry traffic between Brazilian academic sites and both academic and commodity networks in the US and around the world. Commodity peering and transit is contracted in Miami. These links between Brazil and Miami form part of the Americas Lightpaths (Amlight) collaboration funded by institutions in the US and Brazil [Amlight 2013].

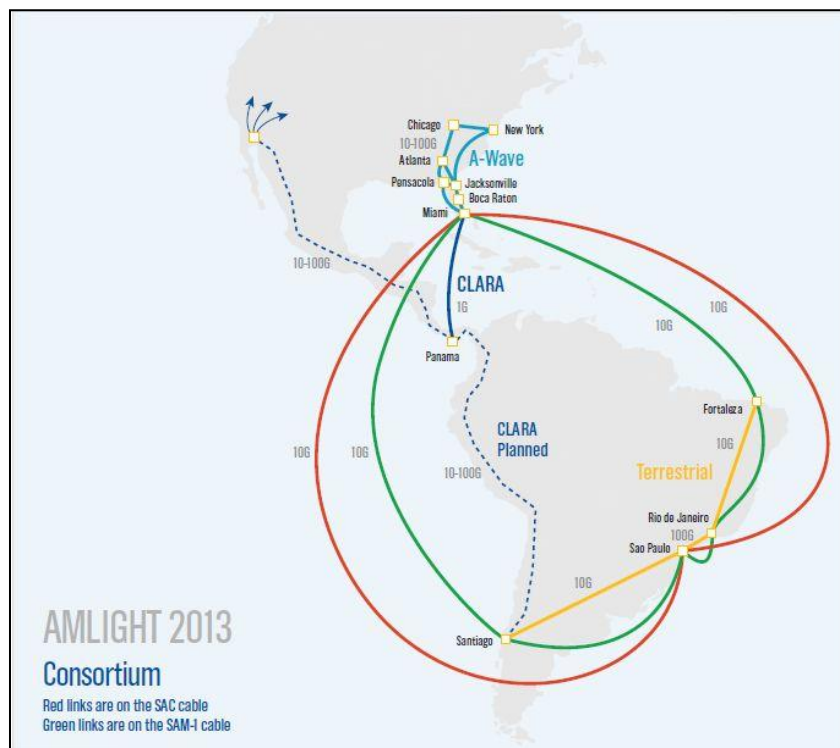


Figure 1: Links between Brazil and the US in 2013 (courtesy of Chip Cox)

The second solution is through RNP's participation in RedCLARA, the regional R&E network in Latin America, of which RNP is a founder member [RedCLARA 2013]. This network links R&E networks in most mainland countries in Latin America, and has been generously supported by funding from the European Commission during the period between 2003 and 2012, by means of the ALICE and ALICE2 projects. This investment has been complemented by cooperative agreements, financed by RNP and the Argentine national network, Innova-Red, for provisioning high-capacity optical infrastructure between Porto Alegre, Brazil, and Buenos Aires, Argentina (financed by RNP), and between Buenos Aires and Santiago, Chile (financed by Innova-Red). Figure 2 shows the topology and capacity of RedCLARA in 2013 – the high capacity optical links Brazil-Argentina-Chile are indicated as 10 Gbps (in black). It is expected that the external link between RedCLARA and GEANT, currently at 2.5 Gb/s, will be upgraded to 5 Gb/s in March, 2014, through a new link between São Paulo and London.

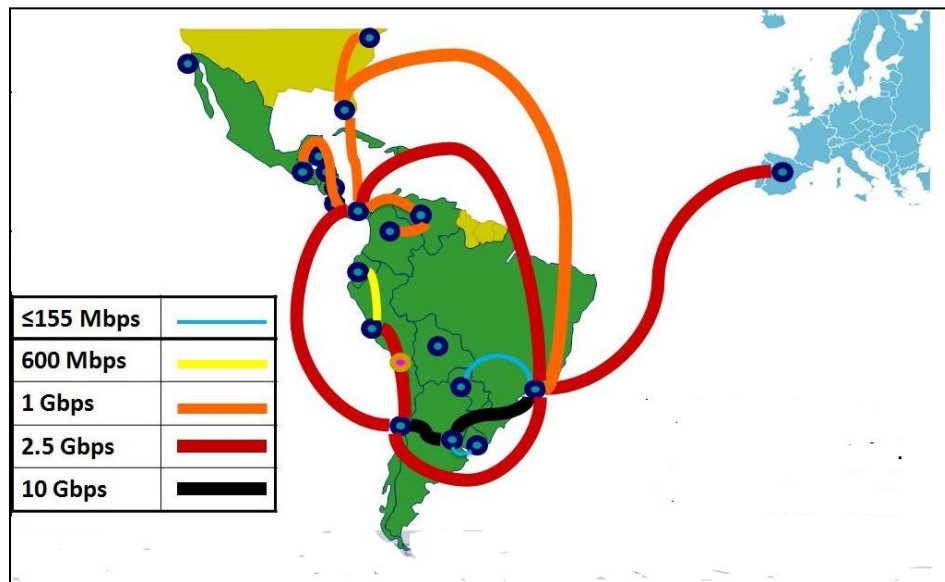


Figure2: RedCLARA topology and capacities in 2013 (courtesy of Florencio Utreras)

## 1.2 The RNP national backbone – the Ipê network

Currently, RNP has a national backbone, using optical wavelength links acquired from telecom operators, most of them at 10 Gb/s. In each capital, RNP has a Point of Presence (PoP), normally installed in a public (usually federal) university, from which RNP provides access to all the university and research institution campuses in that state. Figure 3 presents the topology of the *Ipê* backbone in 2013, showing the interstate circuits of up to 10 Gb/s, interconnecting the PoPs.

A significant alteration in 2013 was the replacement by two terrestrial links of the last satellite link of the national backbone, connecting Boa Vista, in the far North. Boa Vista is now connected using optical infrastructure by a 40 Mb/s link to Fortaleza, in the Northeast, and a 100

Mb/s link to Manaus, in the Amazon region, with both links provided by the telecom operator Oi (partially controlled by Portugal Telecom). The new link to Fortaleza crosses Venezuela and uses the Globenet submarine cable system. The link to Manaus uses underground cable, installed by Oi along the federal highway, BR 174, which crosses several indigenous reservations between Boa Vista and Manaus.

A large fraction of these 800 campi has high-capacity links (at least 1 Gb/s) to the RNP network. RNP has already interconnected at 1 or 10 Gb/s all universities, university hospitals and research centres in the 27 capitals and a handful of major non-capital cities. In these cities, this is done through RNP's own metropolitan optical networks. To illustrate a typical metropolitan optical network, Figure 4 shows the topology of the MetroBel network in Belém, the capital of Pará state, located in the North of Brazil. MetroBel has a 30 km ring using 48 strand cable, with a further 10 km radial extension with 36 strand cable, and connects 32 campi belong to 12 institutions, each one with a 1 Gb/s connection to the RNP backbone PoP.

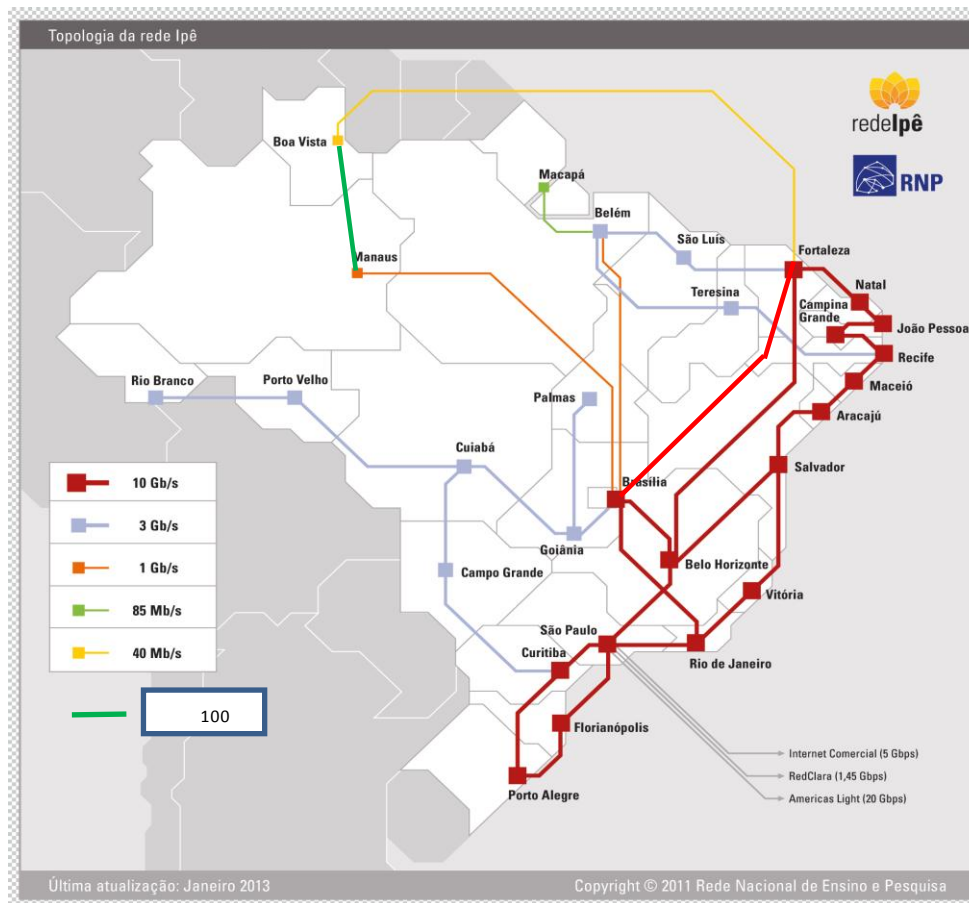


Figure 3 – RNP's national backbone network in 2013

A second set of campi, in smaller, non-capital cities, is connected at capacities between 20 and 100 Mb/s, using optical fibre or radio links to the RNP PoPs in the local state capital.

However, there still exist residual low-capacity connections (less than 20 Mb/s), many of them served through satellite links. The majority of these are located in the Amazon region, where there is practically no land-based infrastructure, and it is necessary to seek a non-conventional solution based on optical fibre. In this article we will focus on a solution using subfluvial optical cables – the use of river courses to provide the infrastructure to install optical communication systems.



Figure 4 - MetroBel – Belém Metropolitan Network topology

The remainder of this paper is organized as follows: Section 2 will describe a number of sub-aquatic (undersea, under lakes and rivers) cable-based solutions used in different counties; Section 3 will describe existing optical infrastructure in the Amazon region of Brazil and Section 4 will discuss a new proposal for subfluvial cables along major rivers in this region. Section 5 will briefly mention similar projects, and some conclusions will be presented in Section 6.

## 2. Some examples of the use of sub-aquatic optical cables as an alternative to overland optical routes around the world

For several years, terrestrial optical cable has been deployed along highways, railways, fluid fuel pipelines and electrical power transmission lines. These overland routes have been used to

support national and regional backbones of telecommunications networks, including Internet backbones. To complement these, there is massive use of submarine optical cables for intercontinental connection of national telecommunications networks, giving them world-wide reach.

However, in many countries or even continents, there are still regions where few or no such overland routes exist or are scarce, notably in areas of difficult access by land and of low population density. Some of these regions have, in the rivers that traverse them, or in coastal seas and oceans, an alternative space for deploying optical cable-based solutions to meet diverse society needs.

The following sections provide examples of the previous use of sub-aquatic optical cables in different parts of the world. Usually, they were installed because overland routes were unavailable (or undesirable) to support optical cable deployment.

## 2.1 ADONES – Angola Domestic Network System

Operational since 2008, ADONES – Angola Domestic Network System is an example of submarine optical cable deployment in coastal waters. The system extends for 1,600 km and has been deployed by Angola Telecom along the Atlantic coast of Angola. From north to South, ADONES interconnects the Angolan cities of Cabinda, Soyo, N’zeto, Luanda, , Porto Amboim, Benguela, Lucira, e Namibe. Figure 5 is a map showing the connections between these cities – it should be observed that there are two separate links between Cabinda and Soyo to provide redundant access to the Cabinda Enclave, physically separate from the rest of the country.

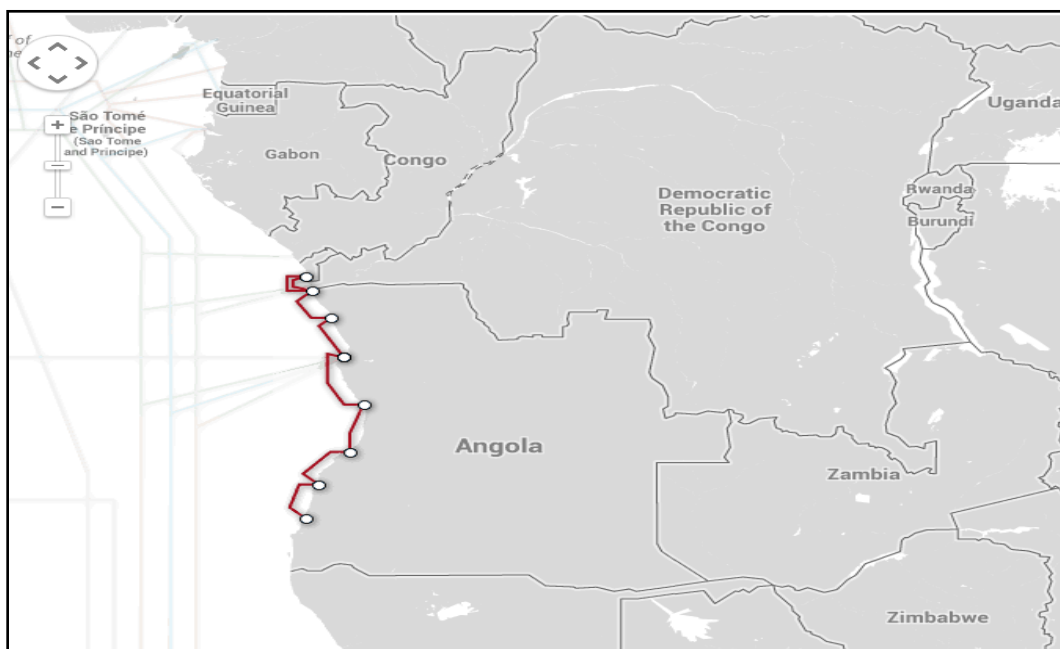


Figure 1 - ADONES submarine optical cable system - [ADONES 2013]

## 2.2 Optical cable across the Matanzas River, connecting Anastasia Island to St. Augustine, Florida, USA

The telecom operator AT&T connected Anastasia Island to the city of St. Augustine in mainland Florida, USA, by means of a 2.3 km subfluvial optical fibre cable crossing the Matanzas River. This cable was deployed in order to substitute another cable which had been carried across the Lion Bridge, which also connects these two locations, and which had been damaged during repair work on this bridge [AT&T,2013].

## 2.3 Optical cable across Duck Lagoon (Lagoa dos Patos), Rio Grande do Sul, Brazil

Between 2010 and 2011, electrical power and optical fibre cables were deployed by the state electric power company, CEEE, across the Waters of Duck Lagoon (Lagoa dos Patos), to connect the cities of Rio Grande e São José do Norte in the state of Rio Grande do Sul, in Brazil, in order to provide both electric power and telecommunications services to the second city. The length of the underwater section of this route is about 1.5 km. The new set of 4 sub-aquatic cables replaces an earlier scheme where power and telecommunications cables were carried across the channel at a height of 72 m. above the water. [CEEE 2013]

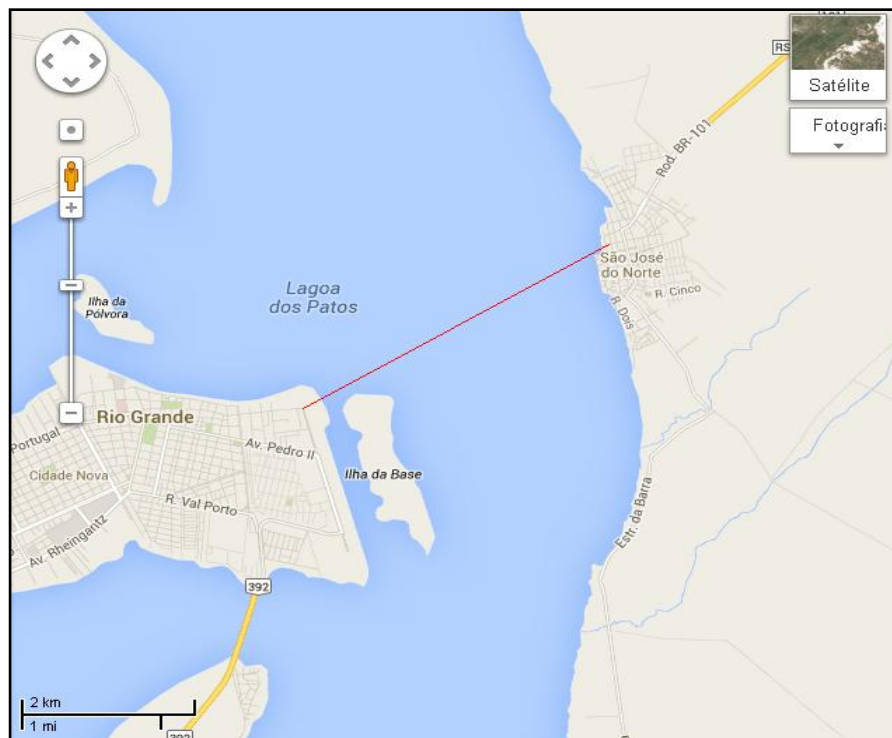


Figure 2 - Optical cable under Duck Lagoon (Lagoa dos Patos), Rio Grande do Sul, Brazil (drawn using Google Maps).

## 2.4 AKORN –Alaska Oregon Network, USA

Deployed by ACS (Alaska Communications Systems Group) in coastal waters of the Pacific Coast of North America, the AKORN (Alaska-Oregon Network) system provides a 3000 km submarine optical cable connection between the USA cities of Anchorage, Homer and Nikiski in Alaska and Florence in Oregon. Figure 7 shows a map of the connections between the two states.

## 2.5 Optical cable across the River Solimões, Amazonas, Brazil

The telecom operator Embratel has built a 12 km optical cable system, crossing the River Solimões in the state of Amazonas, Brazil. The project included a subfluvial optical cable section, and an Overland section, in order to connect Embratel's stations on the two sides of the River Solimões.[Azevedo 2010]

This Project was the first to provide a fibre optic route across the River Amazon system, and substituted previous satellite and radio links.



Figure 3 - AKORN submarine cable system [AKORN 2013]

## 2.6 Optical cable under Lake Constance, Germany,

In 2007, a subaquatic fibre optical cable system was deployed across Lake Constance, connecting the cities of Konstanz and Friedrichshafen, which are on opposite shores of the lake. Figure 8 shows the cable route, linking the two cities.

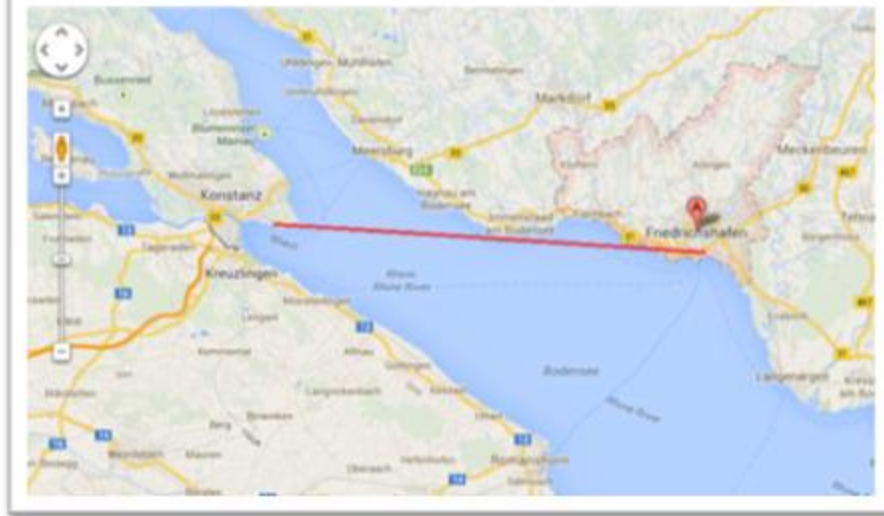


Figure 8 - Optical cable under Lake Constance, Germany (drawn using Google Maps)

### 3. Existing long-distance optical infrastructure in the Brazilian Amazon region

Currently, the following long-distance optical routes have been deployed in the Brazilian Amazon region (see Figure 9):

- Porto Velho – Manaus: optical cable owned by telecom operator Embratel, aerial, using utility poles, constructed along the federal highway, BR 319, which crosses an area of dense tropical rainforest between these state capitals. This was the first optical route which crossed the Amazon River system [Azevedo 2010]
- Tucuruí – Macapá – Manaus: OPGW owned by mobile telecom operator TIM (Telecom Italia Mobile), using electric power transmission lines of Isolux, used to connect large-scale hydroelectric generating facilities at Tucuruí and, in future, Belo Monte, both in Pará state, to population centres in Macapá and Manaus (see Figure 9) [Doile 2010];
- Manaus – Coarí: optical cable owned by Petrobras, Brazil's state-owned oil and gas company, deployed along a gas pipeline from the production centre at Urucu (Amazonas state) to the state capital, Manaus [Petrobras 2009];
- Manaus – Boa Vista: optical cable owned by telecom operator Oi (Portugal Telecom Group), deployed underground along the federal highway, BR 174, which crosses indigenous reservations state between these two capitals. A second OPGW cable links Boa Vista to the border with Venezuela, where it connects to the Venezuelan national network run by CANTV.
- Macapá – Oiapoque, optical cable owned by telecom operator Oi (Portugal Telecom Group), deployed underground along the federal highway, BR 156, through a non-populated area, connecting Macapá to the border with French Guiana, to be completed in December, 2013.



Figure 9 Optical routes already built in the Amazon region (various sources)

Although these optical routes are of undoubted importance to the Amazon Region, as they provide access mainly the endpoints (large cities, hydroelectric plants, gas production centres, national border crossing points), and do not provide access to much of the scattered population of the region, which does not live along these routes, but mostly along the courses of the main rivers of the region.

#### 4. A project to deploy optical cable in the Amazon region

In many parts of the world, there are still regions of difficult access by land and of low population density. Some of these regions have, in the rivers that traverse them, a common solution to meet diverse society needs.

One of them is the Amazon region of Northern Brazil and some neighbouring countries, where there are few roads serving the main cities and where the population lives mainly along the banks of the great rivers that cross it.

The project described here began as a Final Undergraduate Project, under the orientation of the first author of this paper, presented at the National Institute for Telecommunications – Inatel

[Vitor 2012]. This student project was concerned initially with providing a fibre connection across the mouth of the River Amazon, and then upriver to Santarém (Pará state).

RNP has instigated the Brazilian government, and particularly the Communications Ministry, to undertake a much more ambitious project, still in its early stages, of deployment of optical cables along the courses of its major rivers – such as the rivers Amazon, Negro and Solimões.

This proposal for the deployment of such subfluvial optical routes in the Amazon region was launched as a challenge to improve telecommunications infrastructure in the region, improving the availability of both broadband and communications in general, considering that the rivers in this region provide the main means of transport and where, along their banks, most of its population lives.

The main benefits of this project are:

- to create in the Amazon region a telecommunications infrastructure that will accelerate regional integration and development and contribute to the robustness of systems of national defence and policing;
- to establish a solid foundation for the development of research and education networks in the region;
- to contribute to the technological and industrial development of Brazil with global scale and competitiveness.

Besides the ease of reaching and meeting the needs of the riverside populations of these rivers, a cable route along the riverbed damages the environment far less than the construction of a road, that cuts through the tropical rainforest and ends up causing significant environmental damage.

The project is being elaborated together with Padtec ([www.padtec.com.br](http://www.padtec.com.br)), a Brazilian manufacturer of optical systems, seeking close alignment with the intentions of the Brazilian government with respect to its National Broadband Plan.

Figures 10 and 11 show the complete project, with the extension estimated at 7,784 km and comprising six routes, as follows (referring to figures 10 and 11):

- A. Belém – Macapá – Manaus: 2,030 km, (mostly) along the River Amazon (marked in red);
- B. Manaus – Iauareté (border with Colombia), 1,384 km, along the River Negro, (green);
- C. Panacarica – Pacaraíma (border with Venezuela), 744 km, along the River Branco (yellow);
- D. Manaus – Tabatinga (border with Peru and Colombia), 1,696 km, along the River Solimões, (orange);
- E. Itacoatiara – Porto Velho, 1,115 km, along the River Madeira (blue);
- F. Macapá – Oiapoque (border with French Guiana), 815 km, along the Atlantic coast (violet).



State	Pará	Amazonas	Amapá	Rondônia	Roraima	TOTAL
Total population near to routes	3,198,418	2,997,309	633,919	443,058	342,344	7,615,048
Total population along the routes	2,947,076	2,872,946	562,219	443,058	342,344	7,167,643
% population served on routes	92%	96%	89%	100%	100%	94%
Cities	22	33	7	1	5	68
Total number of cities along the routes	13	26	5	1	5	50
% cities along the routes	59%	79%	71%	100%	100%	74%
Total number of RNP clients along routes	13	12	3	0	1	29

(Population count courtesy of Teleatlas 2013)

Table 1 – Population and numbers of campi served by the project (courtesy Padtec)

The first stage of this project (route “A”) is estimated to use about 2,100 km of optical cable, and to cost around US\$ 200 million. Figure 12 illustrates the geographical route of this first stage, interconnecting Belém, Macapá and Manaus, capitals, respectively, of the states of Pará, Amapá and Amazonas in northern Brazil.

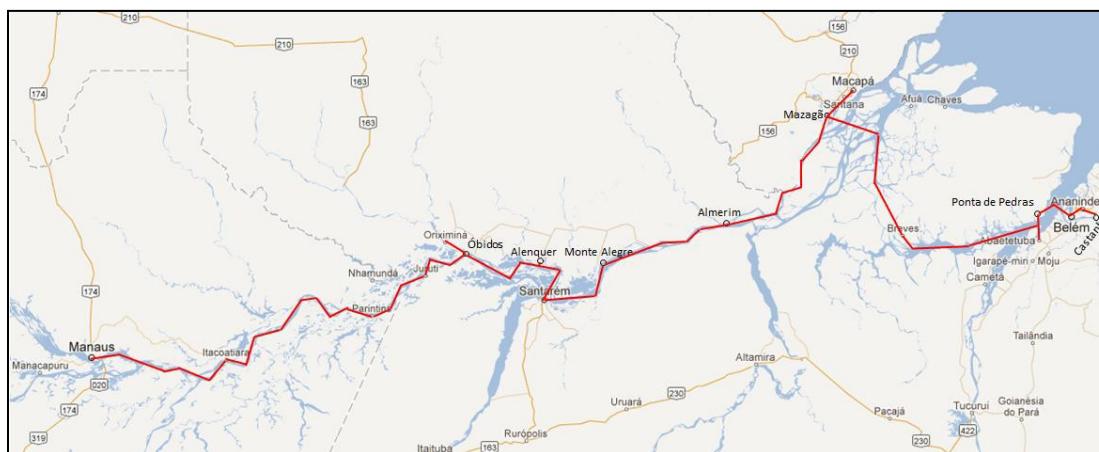


Figure 12 - Optical route “A” : Belém (Pará) - Macapá (Amapá) - Manaus (Amazonas) (courtesy of Padtec, drawn using Google Maps).

## 5. Related projects and studies

Today’s interest in extending optical fibre cables internationally had an earlier equivalent in the second half of the 19<sup>th</sup> Century with the creation of a worldwide system of (electrical) submarine telegraph cables, connecting countries around the Earth. Not surprisingly, the general topology of the “telegraphic Internet” of 1901 is similar to today’s telecommunications networks, although the network then was much more Euro-centric than is the case today [Eastern Telegraph 1901]. However, we might be surprised to learn that one of the cables reaches the city of Manaus in the centre of the Amazon region. This cable was laid along the course of the River Amazon,

following the same Route “A” of section 4, between 1895 and 1896 by the firm Siemens Brothers of London, and an interesting account of the region and the experience of carrying out this project was published by Alexander Siemens in [Siemens 1896].

More recently, a parallel study of deploying optical subfluvial cables in the Amazon region was published in [Garcia 2013]. The author, an engineer from Colombia, also aimed to reduce the digital divide, separating Amazon region inhabitants from their compatriots in the more populous parts of Colombia, and proposed this to be done in collaboration with neighbouring Amazon countries: Brazil, Ecuador and Peru. His proposal was to build a subfluvial cable from Manaus up the River Solimões to Leticia (Colombia) and Iquitos (Peru) (our route “D”) and thence connect them to other parts of these countries. He also assumed that Manaus would be connected terrestrially by way of Venezuela (as it finally was in 2013).

## 6. Conclusion

The courses of the great rivers of the Amazon region are a natural choice for deploying subfluvial optical cables, extending to the riverside communities access to an advanced telecommunications system, providing up-to-date broadband services to the citizen, to society and to education and research institutions.

Bringing a high-capacity optical route to the communities of the region will certainly transform the infrastructure map of the North of Brazil and provide one of the foundations for new economic and social development.

There are several benefits which may be gained from a project of this scale, and we will emphasize the following ones:

- to establish low-latency connectivity between the largest cities in the Amazon region, with extensions to neighbouring countries;
- to provide high-capacity connectivity for research and education institutions, in order for them to make use of Advanced Services provided by RNP, such as videoconferencing, video-classes and other high bandwidth applications;
- to use the RNP networks to connect research workers, teachers and students at federal institutions of technological and higher education to the National System of Science, Technology and Innovation (SNCTI) and to their peers in other countries, giving them the same conditions to use the Internet as their colleagues from other regions of the country;
- to provide a broadband infrastructure for the effective deployment of the National Broadband Plan in the North of Brazil;
- to support the growth of the creation and use of content for telemedicine, telehealth and distance learning;
- to deliver to the North of the country a telecommunications infrastructure which accelerates regional development and contributes to the robustness of national defence and policing;
- to establish a solid base for the development of scientific networks in the North, with possible extensions to neighbouring countries, which have many similar problems to deal with to bridge the east-west and north-south connectivity gaps in the North of Brazil,

providing the country with its most important telecommunications infrastructure both for reaching all parts of the country, and also for establishing cross-border links to all its neighbours to the north and west, effectively integrating the South American continent.

The present stage of the project is to conclude the technical and economic feasibility study, gaining familiarity with the hydrodynamic mechanisms of the Amazon basin, and the dimensioning of the basic parameters of the project. A project of this size will employ the most advanced technologies used in optical communications systems. The main investment will be in optical cables, estimated to cost around US\$ 500 millions for the complete project.

Transmission equipment will need to be dimensioned to cope with the expected traffic flows, and the buildings for providing anchorage for the cable will depend on a local socio-economic analysis.

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## Biographies

**Eduardo Grizendi** is Director of Engineering and Operations at RNP. Since 1990 he has taught at Instituto Nacional de Telecomunicações (Inatel), in Santa Rita do Sapucaí, Minas Gerais, Brazil. He holds a Master of Science in Telecommunication Systems from Inatel and a MBA in Business from Fundação Getúlio Vargas (FGV). He graduated in Electronic Engineering at Instituto Tecnológico de Aeronáutica (ITA). He has worked in the field of telecommunications since 1978, initially in R&D institutions, and afterwards in telecommunications carriers and consulting services.

**Michael Stanton** is Director of Research and Development at RNP. After a PhD in mathematics at Cambridge University in 1971, he has taught at several universities in Brazil, since 1994 as professor of computer networking at the Universidade Federal Fluminense (UFF) in Niterói, Rio de Janeiro state. Between 1986 and 2003, he helped to kick-start research and education networking in Brazil, including the setting-up and running of both a regional network in Rio de Janeiro state (Rede-Rio) and RNP. He returned to RNP in 2001, with responsibility for R&D and RNP involvement in new networking and large-scale collaboration projects.