FUTURE INTERNET TESTBEDS
EXPERIMENTATION BETWEEN
BRAZIL AND EUROPE

Grant Agreement No.: 288356 (FP7)
CNPq Grant Agreement No.: 590022/2011-3

FIBRE-EU

Future Internet testbeds/experimentation between BRazil and Europe – EU

Instrument: ***Collaborative Project***
Thematic Priority: ***[ICT-2011.10.1 EU-Brazil] Research and Development cooperation, topic c) Future Internet – experimental facilities***

D4.2 Report on the Federation physical interconnection

Author: WP4
Revised by:
Alex Moura (RNP)
Dimitris Giatsios (UTH)
Iara Machado (RNP)
Leandro Ciuffo (RNP)
Leonardo Bergesio (i2CAT)
Mayur Channegowda (UnivBRIS)
Michael Stanton (RNP)
Sebastià Sallent (i2CAT)
Due date of the Deliverable: Month 22
Actual submission date: 24/05/2013
Start date of project: June 1st 2011 Duration: 34 months
Version: v.1.0

Project co-funded by the European Commission in the 7th Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	✓

FP7 Grant Agreement No.	288356
CNPq Grant Agreement No.:	590022/2011-3
Project Name	Future Internet testbeds/experimentation between BRazil and Europe – EU
Document Name	FIBRE-D4.2-v1.0
Document Title	D4.2 Report on the Federation Physical Interconnection
Workpackage	WP4
Authors (in alphabetical order)	Alex Moura (RNP) Carlos Bermudo (i2CAT) Dimitris Giatsios (UTH) Iara Machado (RNP) Leandro Ciuffo (RNP) Leonardo Bergesio (i2CAT) Mayur Channegowda (UnivBRIS)
Editor	Alex Moura (RNP)
Reviewers (in alphabetical order)	Alex Moura (RNP) Loïc Baron (UPMC) Carlos Bermudo (i2CAT) Dimitris Giatsios (UTH) Iara Machado (RNP) Leandro Ciuffo (RNP) Leonardo Bergesio (i2cat) Mayur Channegowda (UnivBRIS) Michael Stanton (RNP) Sebastià Sallent (i2CAT) Michael Sioutis (UPMC)
Delivery Date	24/05/2013
Version	V1.0

Abstract

The content of this deliverable presents a discussion towards a working federated environment. The main goal of Task 4.4 is to physically interconnect the European and Brazilian testbeds. A connectivity hub is expected to be established at each continent, one at RNP and one at i2CAT or UnivBRIS, and each hub will interconnect that side's islands and provide access to an intercontinental link between the two hubs. Connectivity issues, as well as other aspects related to the operation of the federation, will be developed. RNP will also be in charge of the discussions related to setting up the links required to interconnect the hubs.

TABLE OF CONTENTS

List of Figures

1 Acronyms

AM	Aggregate Manager
CF	Control Framework
DoW	Description of Work
DWDM	Dense wavelength Division Multiplexing
FIBRE	Future Internet testbeds / experimentation between Brazil and Europe
IM	Island Manager
L2	Layer 2 (OSI Model)
L3	Layer 3 (OSI Model)
MS	Milestone
NE	Network Element
NREN	National Research and Education Network
OCF	OFELIA Control Framework
OF	OpenFlow
OFELIA	OpenFlow in Europe: Linking Infrastructure and Applications
p.	page
PoP	Point of Presence
ROADM	Reconfigurable Optical Add and Drop Multiplexer
ToR	Top of Rack
VLAN	Virtual Local Access Network
VM	Virtual Machine
VPN	Virtual Private Network
WP1	Project Management
WP2	Building and operating the Brazilian facility
WP3	Building and operating the European facility
WP4	Federation of facilities
WP5	Development of technology pilots and showcases
WP6	Dissemination and collaboration

2 Scope

The main goal of WP4 package “Federation of Facilities” is to federate the Brazilian and European testbeds. This deliverable focuses on Task 4.4 “Federation Physical Interconnection”, whose main objective is to establish a connectivity hub on the European and Brazilian side and provide access to an intercontinental link between hubs.

European Commission Information Society and Media
COOPERATION
CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico 60 ANOS
Ministério da Ciência, Tecnologia e Inovação
GOVERNO FEDERAL BRASIL PAÍS RICO É PAÍS SEM POBREZA

3 European Hub

According to the DoW, the objective of Task 4.4. is to physically interconnect the different testbeds or islands that are part of the FIBRE facility. To do so, a possible approach is to establish a connectivity hub at each side of the Atlantic to physically interconnect European and Brazilian testbeds. Each hub must interconnect each side's islands and provide access to an intercontinental link between both hubs.

On the European side, the initial idea of using a central hub split in several options once the problem was been deeply studied. There have been discussions about having one or two hubs to connect to the Brazilian testbeds and also about which kind of link to establish: a dedicated connection through a VLAN, or a VPN over the academic Internet.

The DoW specification about having just one central hub in Europe has being discussed and, currently the possibility of having more than one is being studied.

- Only one hub:

  This keeps the DoW idea of setting a central hub in Europe using a star topology to reach all the European testbeds and link them with the Brazilian testbeds through the Brazilian hub. If this option is adopted, i2CAT or UnivBRIS should act as central hub for the European testbeds and probably use the existing VLAN link to connect with the Brazilian testbeds, although a Layer 3 VPN connection could be also used.

- No central hub with two connection points:

  In this case, no star topology is needed and more than one European testbed could be connected to the Brazilian hub(s).

  Because of the fact that there are two intercontinental links already deployed in i2CAT and University of Bristol (see Section 4), this option could use both links. The main issue of this option is that it generates a loop in the L2 segment composed by all the federated testbeds, since the connection Europe-Brazil has two possible paths. One possible solution is to use one connection for control traffic and the other one for experimental traffic. In this way, a dedicated bandwith is achieved for each type of traffic in the intercontinental link at the time that we set two links crossing the ocean which could be used in the future for different purposes.

3.1 FIBRE internal networks

To support the operation of the experimental FIBRE network, two out-of-band networks have been designed; the control and the management network.The control network, by design, is meant to support and make available the different FIBRE services, like the entry point for experimenters to the testbed, the access to the testbed orchestration software or the access to the experiment resources (e.g. a virtual-machine), as well as other FIBRE internal services, such as DNS. In addition, the control network may also be connected to other local-island resources (e.g., OFELIA islands, non-FIBRE).

Within Europe, the control network of the islands based on OCF are reachable by a L3 VPN that the registered users can access. On the other hand, UTH's Nitos testbed's, which is based on OMF, is available directly on Internet. In order to make possible that the components of the different control frameworks communicate, there are two possibilities:

- OCF-based islands export a public IP.
- NITOS testbed connects to the internal VPN.

The management network is used for setting up and maintaining the infrastructure itself (i.e., something that should be shielded from the experimenters) and is only available to the administrators of an island. FIBRE users are not expected (or allowed) to use the management network, or send traffic over it. Since the purpose is local management, island management networks do not need to be interconnected with other island management networks.

Finally, the experimental network is the one used to transport user's experiments data. It is OpenFlow based and follows a VLAN-based approach to slice the different experiments.

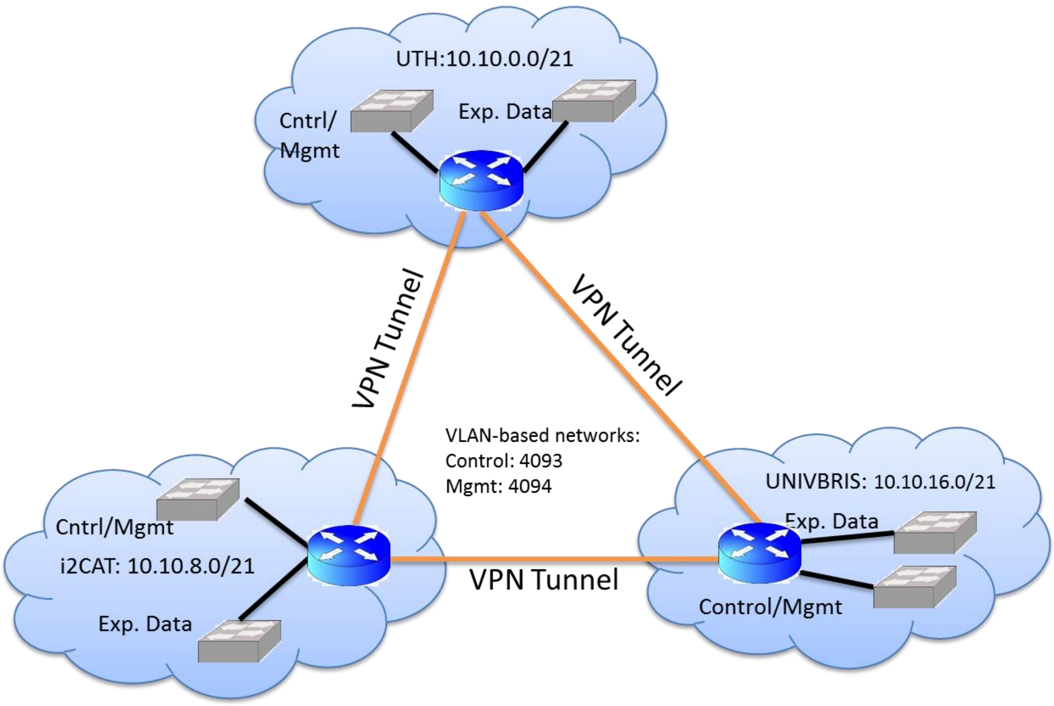


Figure 1: European islands and their interconnection

3.2 FIBRE inter island connections

On the other hand, the technology to establish the links between different islands is another matter of study. The possibilities evaluated are:

- Connections via VPN:

  VPN connections over the Internet allow any testbed in the European side to be the central hub or one of them. The main disadvantage is that no quality of service is guaranteed, the bandwidth of the connection is subjected to network usage.

- Connections via a transport VLAN:

  A connection through a dedicated VLAN through NRENs that link Europe and Brazil could provide a trustable connection with a guaranteed bandwidth.

- It is also possible to combine both previous approaches using the GEANT circuits for the experimental network and let the control network to be supported by a legacy L3 VPN connection.

Currently, two VLAN links have been established between Europe and Brazil: one from University of Bristol through Internet2 and the other one from i2CAT through RedCLARA. Both links end in the Brazilian side at RNP in Sao Paulo. More info is available in Section 4 and Schemas are shown in Sections 7.3 and 7.5. If the one-hub solution is adopted, one of these links should be choosen as the central hub in Europe and deploy a star topology centered in its hub. At the same time, VLAN links via GEANT have been established between the different European Islands, which will be commented in the respective following sections.

The use of a transport VLAN provided by GEANT imposes some constraints at least in the deployment of the OCF-OpenFlow based islands. The fact of using a transport VLAN means that all the control and experimental traffic going from one island to another one needs to be tagged in order to access the virtual link. In addition, OpenFlow-based islands in i2CAT and UnivBris slice the different experiments based on VLANs, and control and management networks may be also VLAN-based. The traffic of a specific experiment, which is already tagged in order to recognize the slice that it belongs to, needs to be double tagged if it needs to arrive to a network element in another island. IEEE 802.1QinQ appears as a requirement. To accomplish this, it is required that the entry-point gateway of all the islands supports QinQ and performs the task of tagging/untagging in/out traffic.

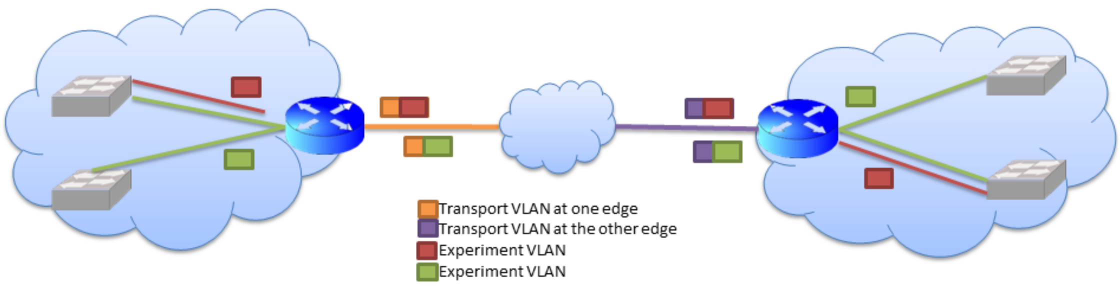


Figure 2: QinQ at the Islands gateways

4 EU-BR Intercontinental links

One of the central points of the FIBRE project is the physical interconnection of testbeds between Europe and Brazil in order to achieve their federation, a quite demanding operational effort for the testbeds administrators. To achieve this, as commented in the previous sections, two links have been established: one from i2CAT testbed in Barcelona, and the other from University of Essex, now University of Bristol.

The first L2 circuit connects i2CAT to RNP in Sao Paulo. i2CAT is connected to CESCA [1] who provides connection to RedIRIS network [2]. RedIRIS is the Spanish academic and research network and gives access to the GEANT network. Through this network, RedCLARA[3] in South America is reached and finally linked to RNP in Sao Paulo.

A point-to-point circuit has been requested to GEANT until the end of the project, March 2014. The circuit goes through a Layer2 VPN and has a bandwidth of 100Mbps.The possibility to increase this bandwidth may arise if the usage of the links justifies it. The i2CAT-RNP link has been established and tested with the Brazilian side.

The UK-BR link was established between the University of Bristol and the University of Sao Paulo (USP) and is functional. UNIVBRIS is connected to the local NREN Janet network [4] and from there to GEANT, which provided international connectivity with Internet2 [5]. Internet2 provides connection with the endpoint in Sao Paulo in Brazil. The provided link has a bandwidth of 1Gig and 20 shared VLANs. Figure 3 shows the links between Europe and Brazil.

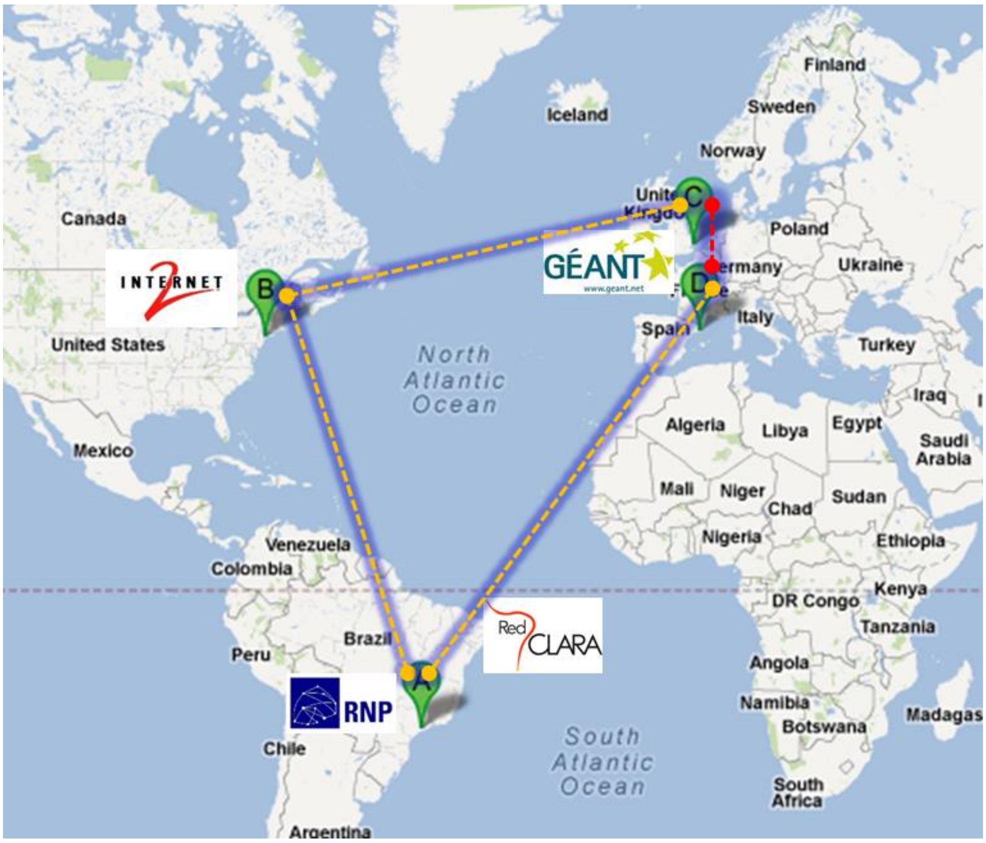


Figure 3: Links between Europe and Brazil

5 Europe islands

5.1 i2CAT Island

i2CAT FIBRE island is co-located with the OFELIA testbed infrastructure but with detached infrastructure. The present island facility comprises 3 OpenFlow enabled switches and 5 servers (one as a host control framework, one for development VM hosting, and three for production VM hosting). (See deliverable document *MS5-Report on the list of hardware purchased* [7] for more details).

We currently study deploying several Wi-Fi access points in a floor of the building of the Castelldefels UPC University campus where the i2CAT testbed is located, in order to give the APs an interesting role in the infrastructure. It is also expected that in a next phase, the i2CAT FIBRE testbed will be connected to a DWDM optical ring based on ROADM technology, that i2CAT is part of jointly with other Catalan institutions, which is deployed in the Barcelona metropolitan area.

The FIBRE i2CAT island is connected to a router in i2CAT premises that provides access to the other European and Brazilian islands as explained in Sections 4, 7.1, 7.2 and 7.3.

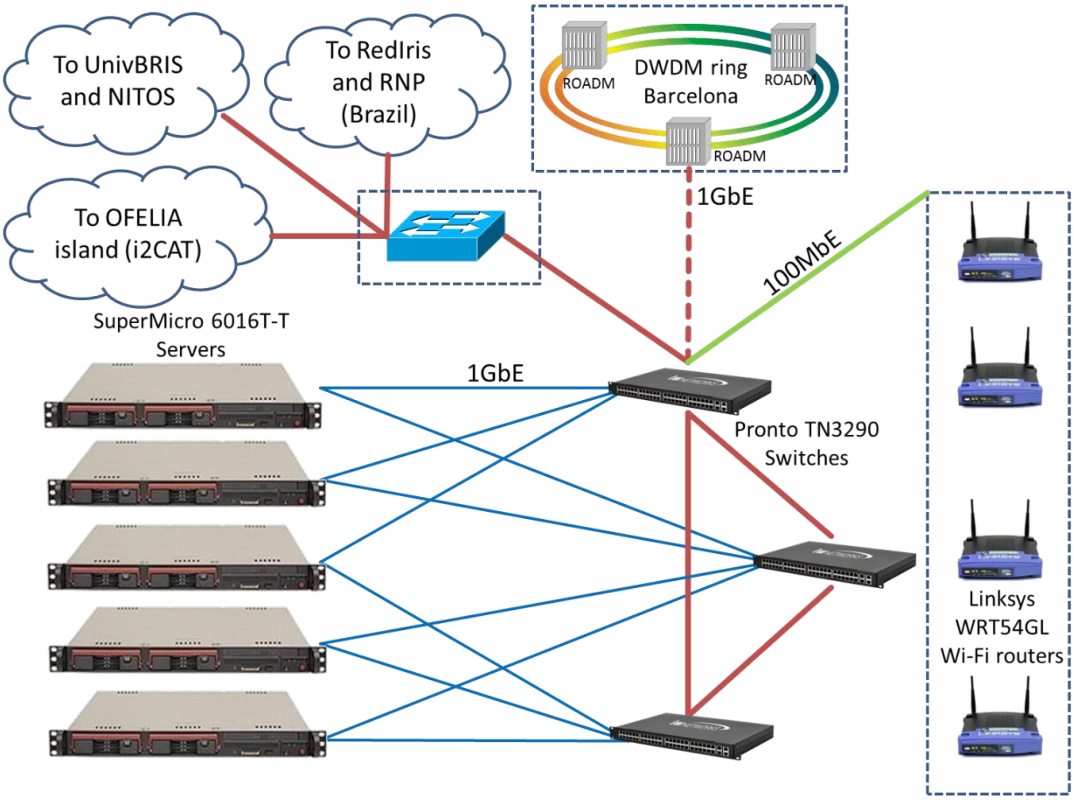


Figure4: i2CAT FIBRE testbed infrastructure

5.2 UnivBRIS Island

UnivBRIS FIBRE island is co-located with the OFELIA testbed infrastructure but with detached infrastructure. The island facility mainly comprises OpenFlow enabled switches, servers to host control framework, XEN virtual machines, and optical equipment to support technology pilot and sub-lambda investigation. (See deliverable document *MS5-Report on the list of hardware purchased* [7] for more details).

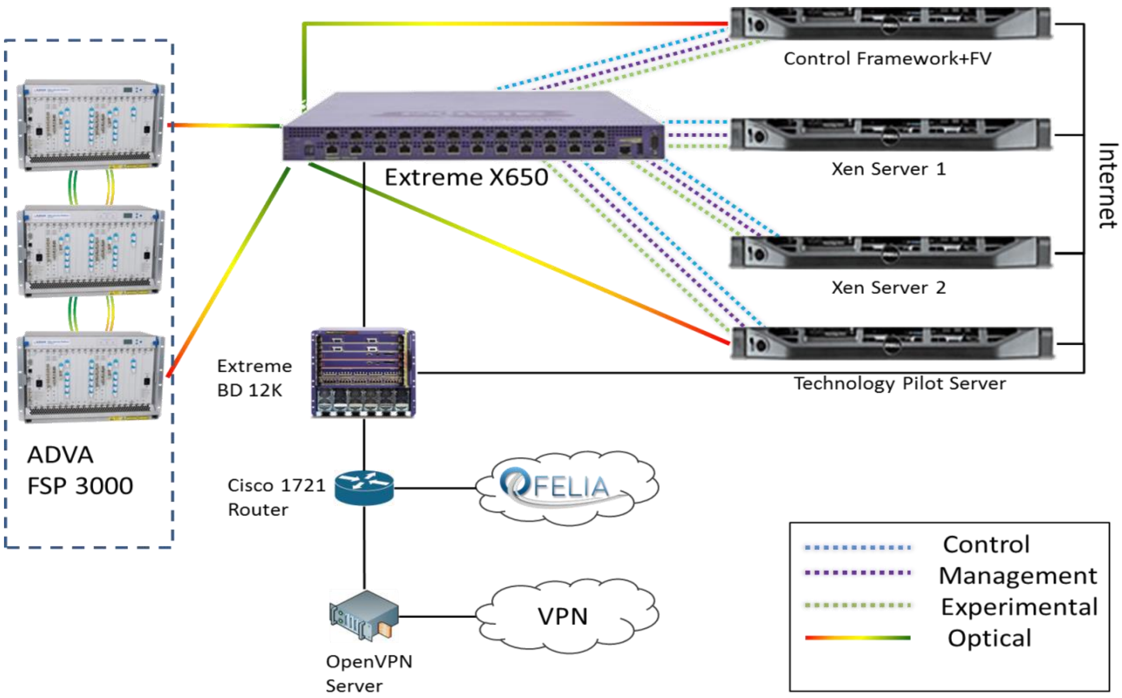


Figure 5: Current UnivBRIS FIBRE Infrastructure

UnivBRIS is connected to EU island over the GEANT. It has a 1Gig connection to i2CAT and 100Mbps to UTH via a VLAN- based circuit over its local NREN JANET. UNIVBRIS will run a VPN connection to each EU endpoint (UTH & i2CAT) and peer the control and management traffic though this VPN connection over GEANT.

Regarding connectivity, Brazil UNIVBRIS will use the Internet2 connection with 2 VLANs over a 1Gig connection for both control & experimental network traffic. It is connected to the University of Sao Paulo via RNP backbone in Brazil.

European Commission Information Society and Media | COOPERATION | CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico 60 ANOS | Ministério da Ciência, Tecnologia e Inovação | GOVERNO FEDERAL BRASIL PAÍS RICO É PAÍS SEM POBREZA

5.3 UTH Island

The overall topology of the NITOS testbed is depicted in the figure below:

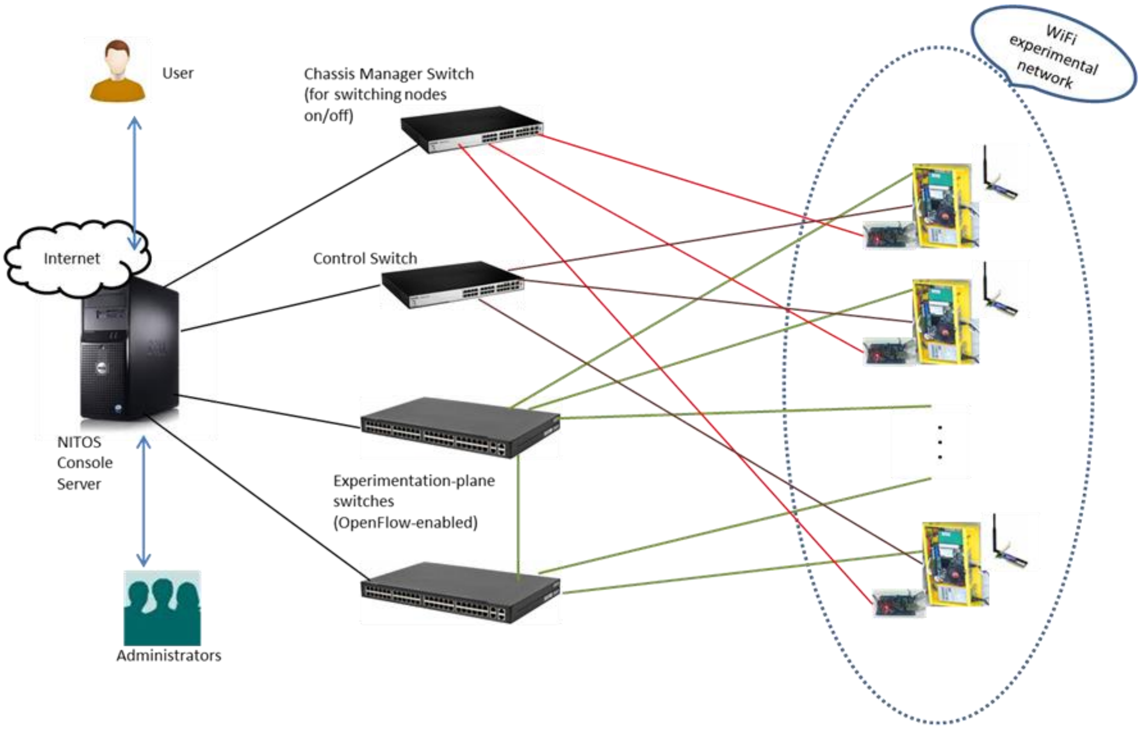


Figure 6: NITOS topology

The two OpenFlow switches are physically connected together, while all of the existing NITOS nodes are physically connected to the switches, forming a programmable wired experimental network (See deliverable document *MS5-Report on the list of hardware purchased* [7] for more details).

Approximately half of the NITOS nodes are connected to the first Pronto switch and the rest of them to the second Pronto switch. The switches are connected with a gateway that is the physical end-point of the GEANT VLAN interconnections between UTH and the other FIBRE islands as explained in Sections 4, 7.2 and 7.4. This topology enables efficient experimentation with use of resources of NITOS and other multiple FIBRE islands.

6 Brazilian Islands

The overall topology of the FIBRE-BR Islands is depicted in the figure below:

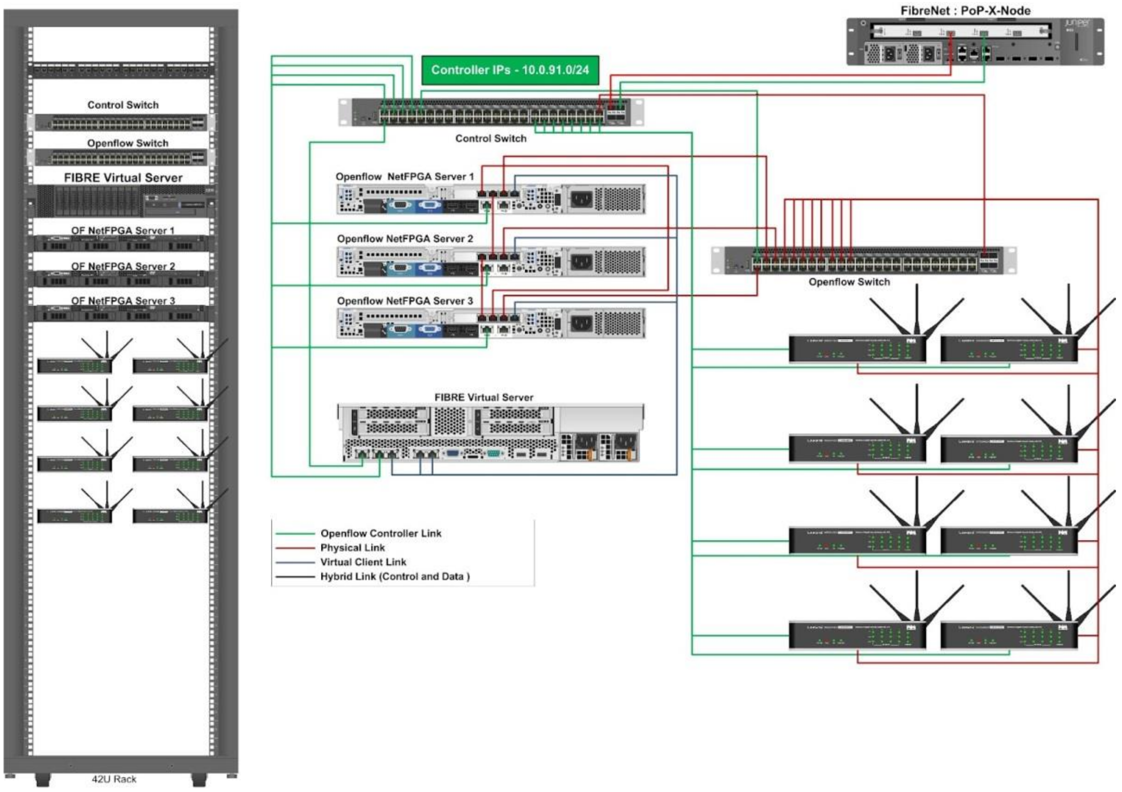


Figure 7 - FIBRE-BR Island Topology

The OpenFlow switch has 48 interfaces and 3 OpenFlow nodes based on NetFPGA boards. The main characteristic of the Brazilian island topology proposal is the addition of a Top of Rack (ToR) switch to connect all equipment's management (console) interfaces.

The OpenFlow switch is physically connected to NetFPGA Servers and ORBIT nodes (where available), while all islands' equipment are physically connected to a second switch, that will be the top of rack (ToR) switch for management and, this way, forming a programmable wired and wireless experimental network.

While it is expected that all islands have the same topology, each has some of its own characteristics regarding rack equipment and physical connections and network access to FIBRE Backbone, so each will be presented separately in the following sections.

The international access to European islands, in a first phase, will be concentrated in RNP PoP at Sao Paulo, where all RNP's international circuits are connected.

6.1 BA - UNIFACS Island

The UNIFACS island network access topology is depicted in the figure below:

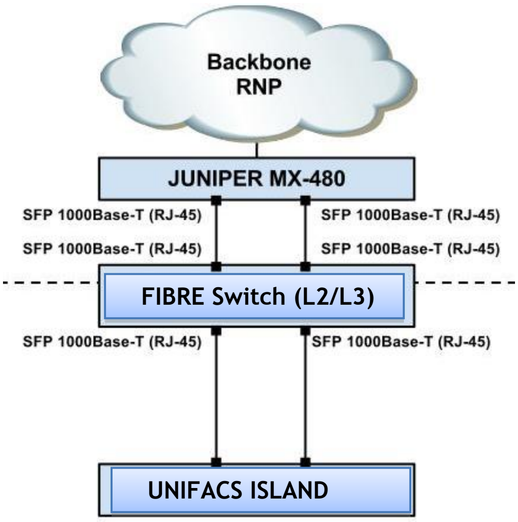


Figure 8 - UNIFACS Island Network Access Topology

6.2 DF - RNP Island

The RNP island is collocated at the RNP Internet Data Centre (IDC) at Brazil's capital, Brasília - DF (Federal District). The island's network access physical topology is shown in the figure below:

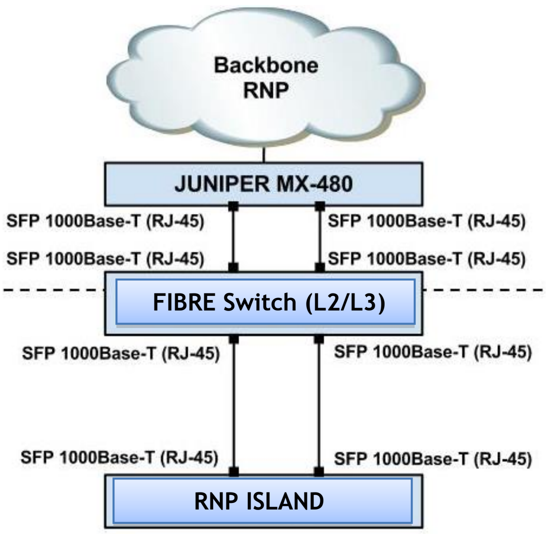


Figure 9 - RNP Island Network Access Topology

6.3 GO - UFG Island

The UFG island topology is shown in the figure below:

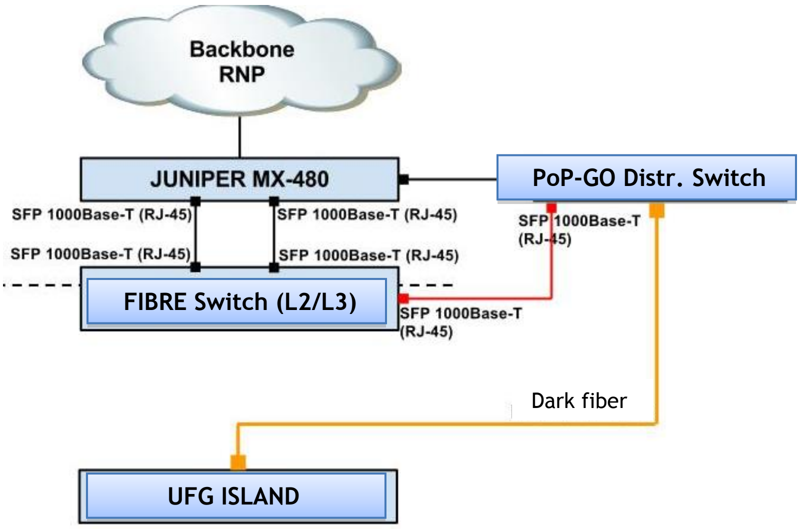


Figure 10 - UFG Island Network Access Topology

6.4 PA - UFPA Island

The UFPA island topology is shown in the figure below:

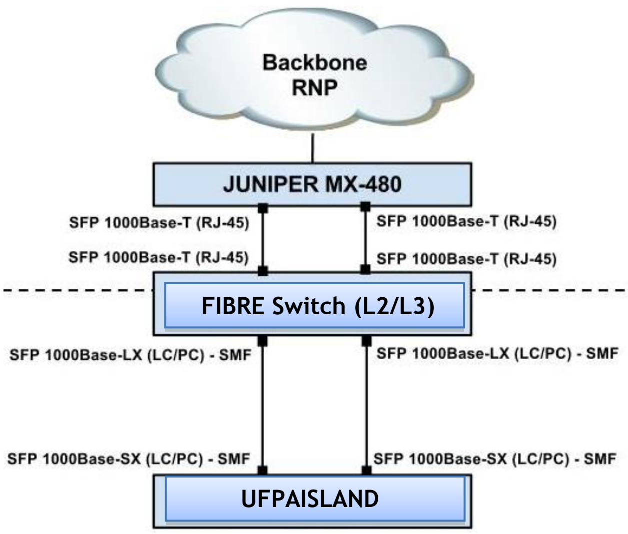


Figure 11 - UFPA Island Network Access Topology

6.5 PE - UFPE Island

The UFPE network access island physical topology is shown in the figure below:

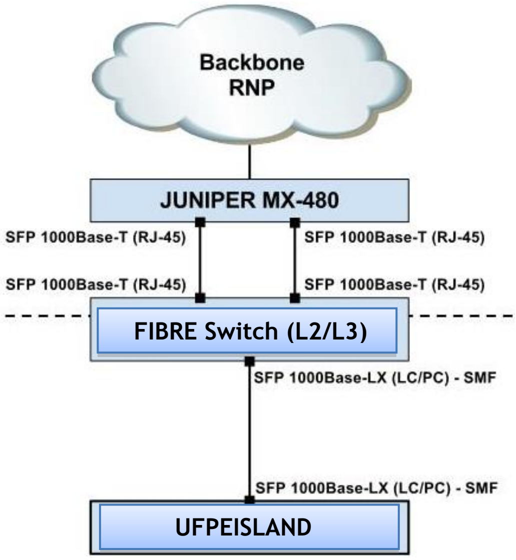


Figure 12 - UFPE Island Network Access Topology

6.6 RJ – UFF and UFRJ Island

The UFF, UFRJ (and possibly CPqD) islands' network access physical topology is shown in the figure below:

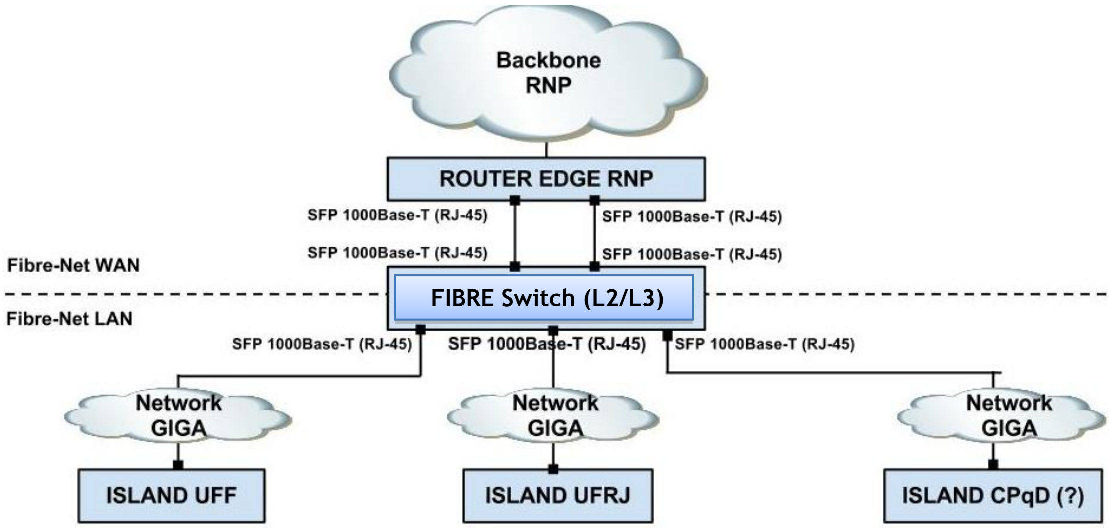


Figure 13 - UFF and UFRJ Islands Network Access Topology

6.7 SP – CPqD, USP and UFSCar Islands

The USP island network access topology is shown in the figure below:

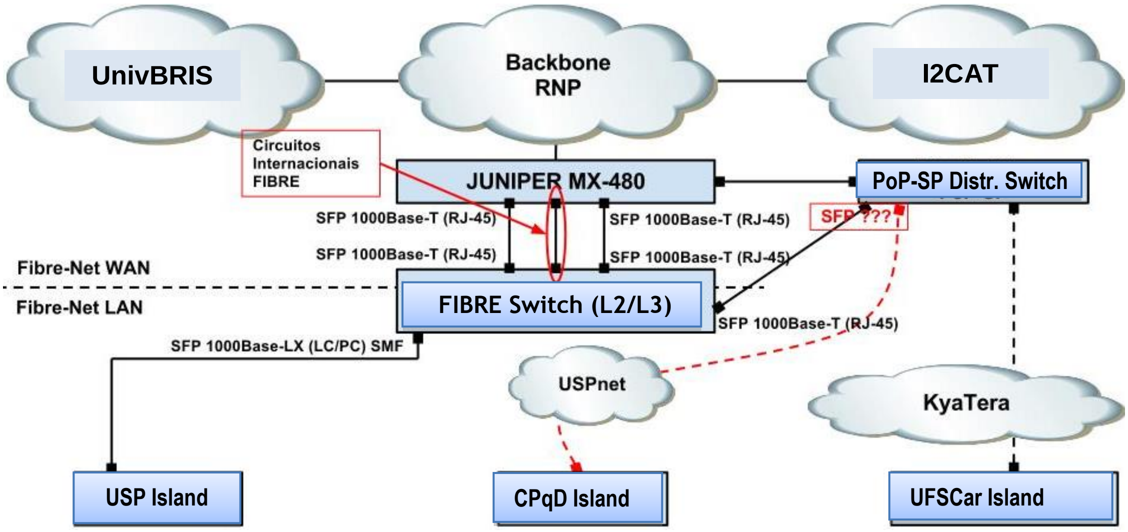


Figure 14 - CPqD, UFSCar and USP Islands PoP Access Topology

6.8 FIBRE Backbone

Since all FIBRE-BR islands are located in universities with access to the RNP backbone, a project was developed with the participation of the RNP R&D and Engineering divisions, that would allow the experimental traffic between islands to be exchanged on a direct fashion between the geographically dispersed islands, using own FIBRE-BR switches and Layer 2 circuits (Ethernet Virtual Circuits – EVCs) in order to have isolation between production and experimental traffic.

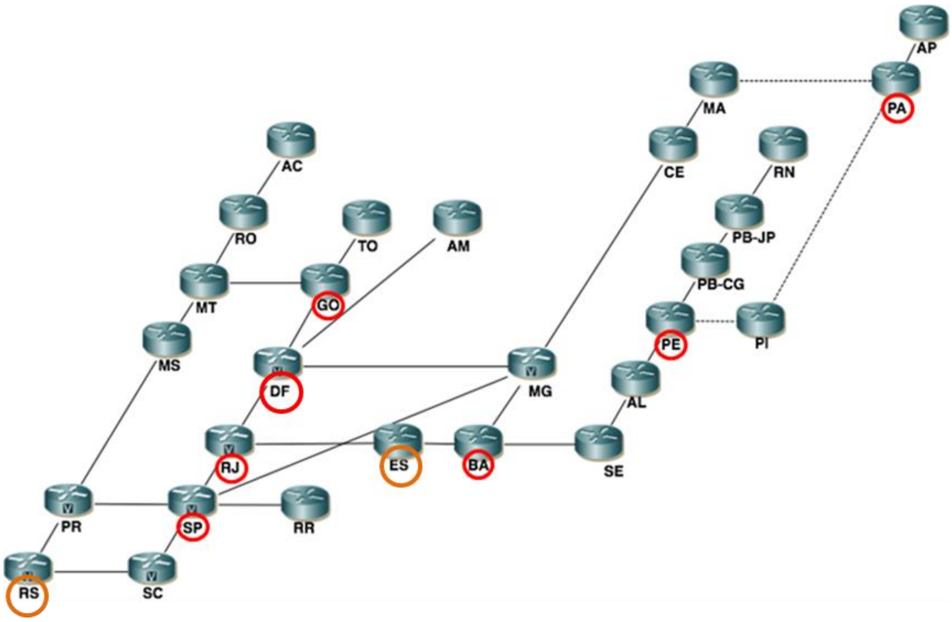


Figure 15 - RNP backbone physical topology

The RNP Backbone will offer a virtual backbone, by using Layer 2 transport circuits between the FIBRE-BR Backbone switches from Datacom (a Brazilian network equipment manufacturer) which have OpenFlow support. The virtual backbone will be an overlay network over the physical RNP backbone.

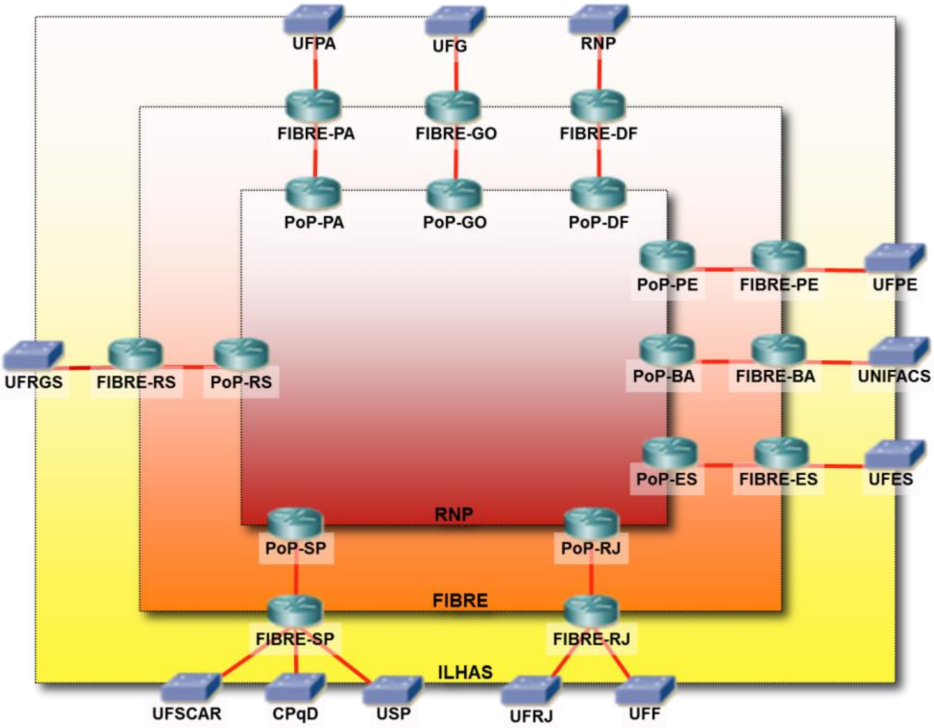


Figure 16 - FIBRE-BR overlay network over the RNP backbone

The FIBRE-BR Backbone will be built using nine standalone Datacom Metro Switches Model DM4000 Series, an equipment with Layer 2 and Layer 3 features, which are being deployed at each RNP PoP that will connect a FIBRE Island and will be placed between each RNP core router on the PoP and the local island(s) hosted at the universities or research centres' domains.

Figure 17 - Datacom DM4000 Series OpenFlow switch

In most cases the universities themselves host the RNP PoP and have their own network domains separated from the universities' campus networks. However, there exist some exceptions where the development of a network access project for each island was required.

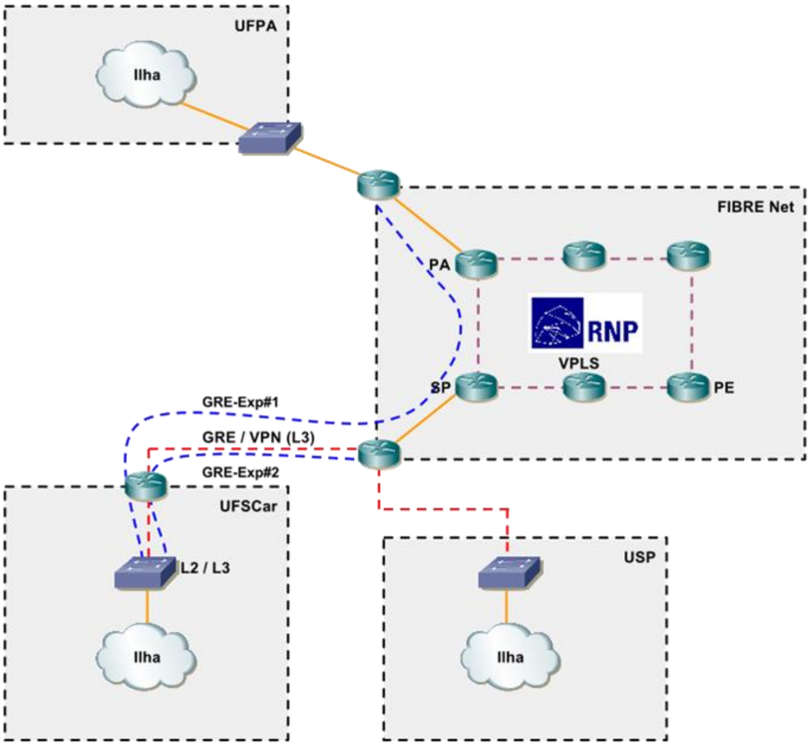


Figure 18 - Example of communication with different network access solutions for UFPA and UFSCar islands

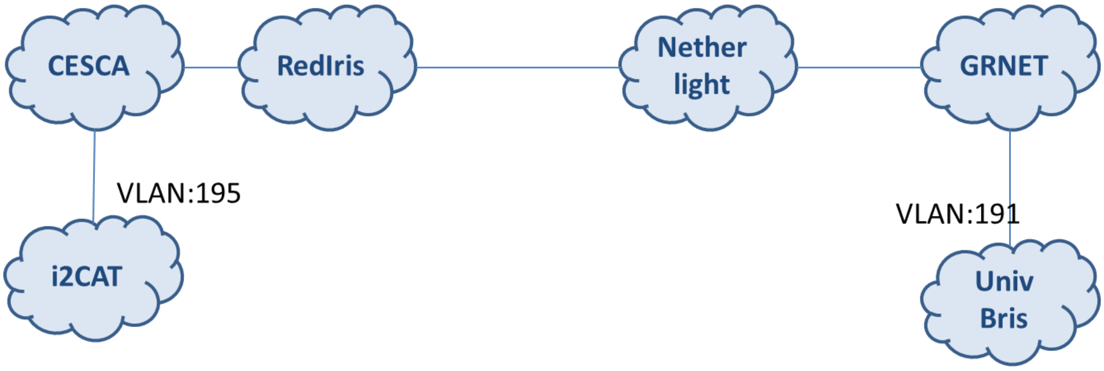
In the initial phase, the FIBRE-BR Project will be responsible for configuring and operating the Datacom switches that will act as the FIBRE-BR Backbone “core routers”. This way, the RNP Engineering and Operations teams, that operate the production backbone, will not be overloaded with support requests and the FIBRE-BR will have more freedom and flexibility with the virtual network operation.

7 Interconnections

7.1 i2CAT – UnivBRIS

i2CAT had already started the request for a circuit to GEANT for the interconnection of the i2CAT and the former University of Essex infrastructures due to their collaboration in the OFELIA project. The process began on March 2013; the circuit was attended and later configured at the end of June 2012.

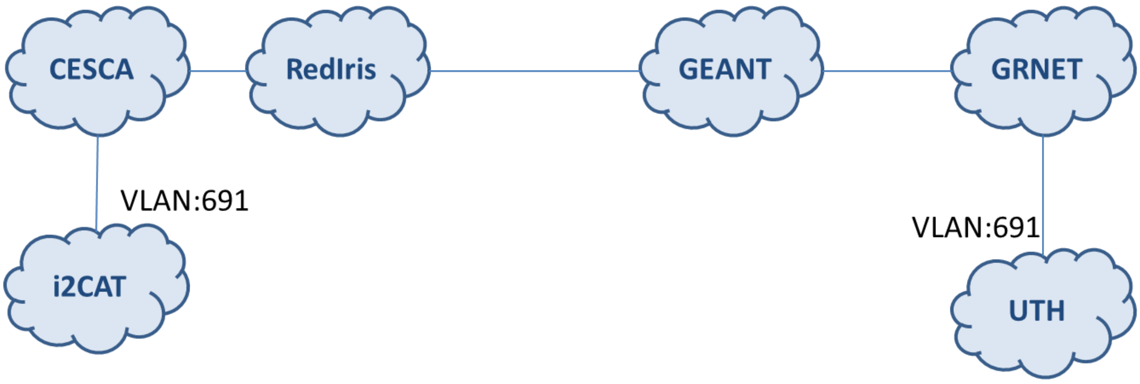
The link from i2CAT is connected to CESCA [1] who provides connection to RedIRIS network [2]. RedIRIS is connected to the Nether light [6] GLIF. Finally, UnivBRIS is connected to Nether light.



The link between i2CAT and UnivBRIS has a bandwidth of 1Gbps. It is operational and point to point testing has been performed.

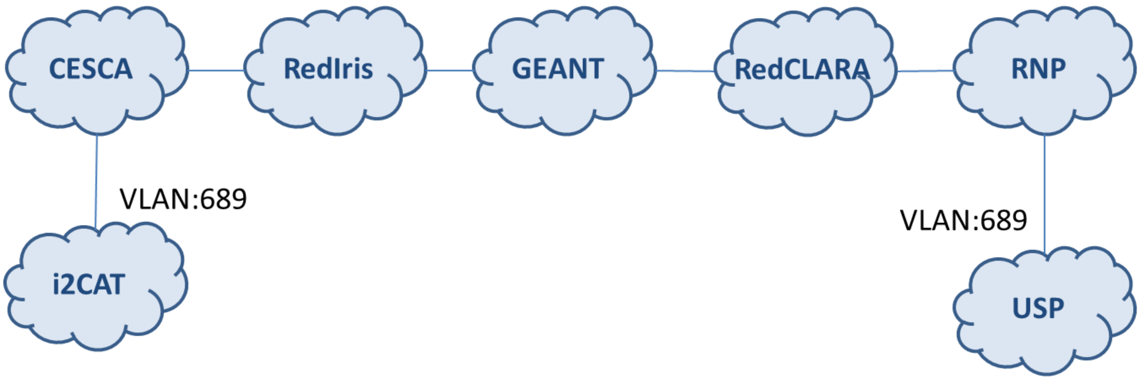
7.2 i2CAT – UTH

A VLAN circuit through GEANT from i2CAT to UTH has been established with a bandwidth of 100Mbps. The link is operative and a point to point test has been performed.



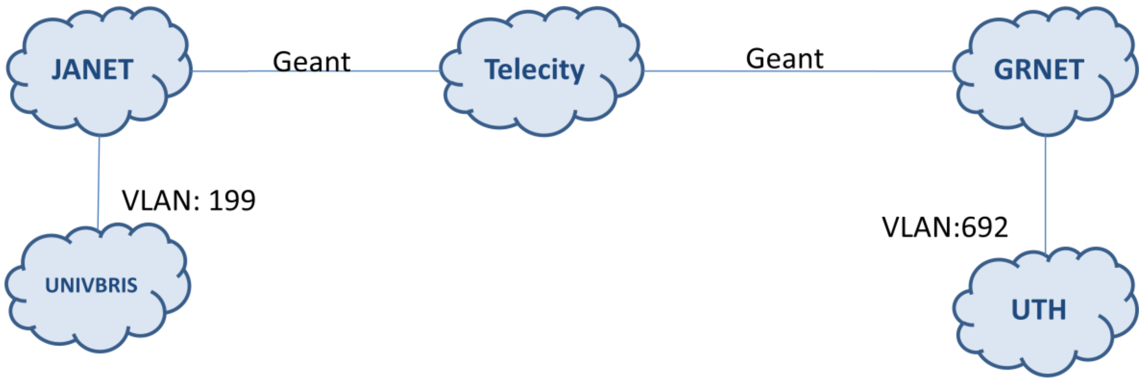
As explained in Section 4, i2CAT gets access to GEANT network. UTH is connected to GRNET [7], the Greek NREN, which is also connected to GEANT, establishing the VLAN circuit described previously.

7.3 i2CAT – RNP



The link between i2CAT and RNP is described in Section 4 (about intercontinental links). It has a bandwidth of 1Gbps. It is operational and a point to point test has been performed.

7.4 UnivBRIS – UTH



The link between UnivBRIS and UTH has a bandwidth of 100Mbps. It is operational and a point to point test has been performed.

7.5 UnivBRIS – RNP

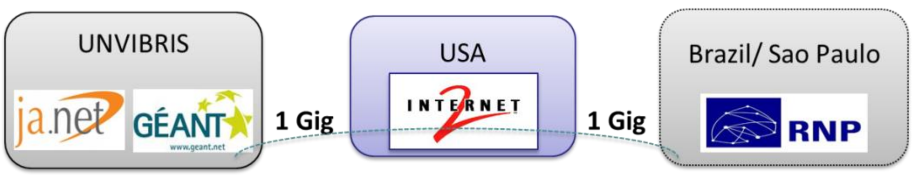
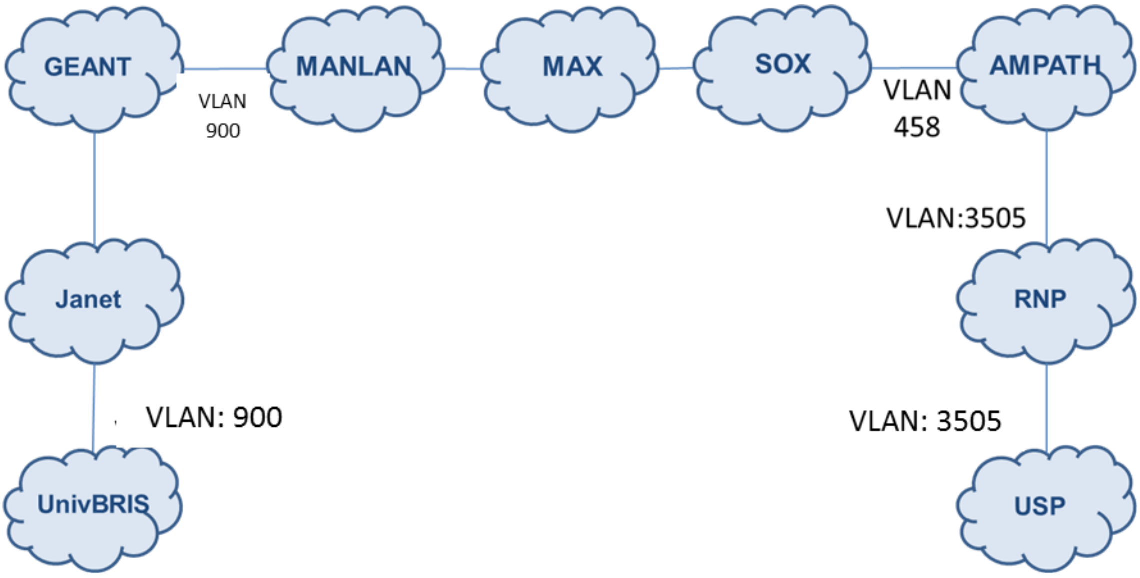


Figure 19 - EU-Brazil connectivity layout over Internet2

The University of Bristol, UK FIBRE Island is connected to University of Sao Paulo, Brazil over the Internet2 connection. It shares a 1Gig connection with OFELIA project and is isolated using

VLANs. Bristol island uses the local JANET NREN to reach the GLIF connection which connects it to Internet2 and the terminating connection of Internet2 at Amlight leads to Brazilian RNP backbone and finally to Sao Paulo. The different networks (control, management & data) are separated on different VLANs making use of the 20 allocated VLANs for the connection. A router at each end is responsible for the inner VLAN routing and can be rate limited ensuring proper bandwidth for OFELIA and FIBRE projects that share the link.

The connectivity details are shown in the following figure:



The link between UnivBRIS and RNP has a bandwidth of 1Gbps. It is operational and a point to point test has been performed.

8 FIBRE and OFELIA

FIBRE resources will be made available in the OFELIA testbed. To achieve this, a physical link between islands of both testbeds must be established. In i2CAT premises, a switch of each testbed will be linked to allow intra-federating the i2CAT FIBRE AMs with the i2CAT island OCF.

Once the physical link is established, it is easy to add the Aggregate Managers that control the other island's resources so that the CF can add these resources to its own island resources and provide them to any experimenter who wants to use them.

Based on the connectivity and load performance of i2CATs OFELIA & FIBRE integration being satisfactory, UNIVBRIS will adopt the same configuration to connect both the facilities.

9 FIBRE and OneLab

NITOS facility, the main wireless testbed of ONELAB, has updated its equipment with two OpenFlow switches in the context of FIBRE. These OpenFlow switches have replaced the previous L2 switches, enhancing the experimentation with heterogeneous resources. In this way, the FIBRE resources (OpenFlow switches) are combined with the OneLab resources (wireless nodes) giving the opportunity to the user for joined experimentation.

In addition, the PLE nodes are publicly accessible through the Internet, following the main notion of PlanetLab testbeds. This feature enables the interconnection of PLE nodes with all FIBRE resources based on a best-effort approach.

The NITOS wireless nodes, the PLE nodes and the FIBRE wireless testbeds in Brazil are intra-federated under the umbrella of the FIBRE and OneLab adopted OMF framework, enabling the experimentation with heterogeneous resources.

10 Reference documents

1. http://www.cesca.cat/en/cesca
2. http://www.rediris.es/
3. http://www.redclara.net
4. https://www.ja.net/
5. http://www.internet2.edu/
6. http://www.surfnet.nl/en/Thema/netherlight/Pages/Default.aspx
7. https://www.grnet.gr/en
8. WP3 MS5 Report on the list of hardware purchased

European Commission Information Society and Media
COOPERATION
CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico 60 ANOS
Ministério da Ciência, Tecnologia e Inovação
GOVERNO FEDERAL BRASIL PAÍS RICO É PAÍS SEM POBREZA

"*This work makes use of results produced by the FIBRE project, co-funded by the Brazilian Council* for Scientific and Technological Development (CNPq) and by the *European Commission within its Seventh Framework Programme.*"

END OF DOCUMENT