



# Advances in developing a Future Internet testbed in Brazil

2nd Workshop of the INCT for Web Science Research  
Aug 2-3, 2011 – Rio de Janeiro

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# Worldwide Future Internet testbed initiatives



Country	2005	2006	2007	2008	2009	2010	2011
USA - GENI	planning	→		deployment spiral1	spiral2 OpenFlow	spiral3	→
EU - FIRE				1 <sup>st</sup> call		2 <sup>nd</sup> call	→
Japan - AKARI				→			
Korea - FIF					→		
China					→		
Brazil				WS-FIA proposal	GIGA Phase 2	WS-FIA start	FIBRE start

# Future Internet (FI) activities and plans



- Brazilian researchers have been tracking FI initiatives in other countries since 2007, and wider discussion and activities began in 2009, with:
  - Nick McKeown’s keynote address on OpenFlow and Software-defined networks to INFOCOM in Rio de Janeiro
  - the reactivation of Project GIGA, and the funding of other FI projects
  - the understanding reached by the Brazilian government and the European Commission on joint funding of ICT projects
- The annual Brazilian Symposium on Computer Networking has also debated this topic since 2009, and has included the Workshop on Experimental Research in FI since 2010.
- The growing awareness in the networking community that to participate in FI R&D is of strategic importance to the country still needs to be translated into more widely available funding.

# The origins of WS-FIA



- The Future Internet Architecture activity of the Web Science Institute (WS-FIA) was proposed in 2008, with the participation of research groups led by:
  - Michael Stanton (RNP e UFF)
  - Iara Machado (RNP)
  - Antonio Abelém (UFPA)
  - José Augusto Suruagy Monteiro (UNIFACS)
  - Tereza Cristina Carvalho (USP)
  - Luiz Cláudio Schara Magalhães (UFF)
- Objectives:
  - Provide the means of carrying out experimental research into Future Internet, through the building of a Future Internet (FI) testbed facility
  - Contribute to research into Future Internet Architectures

# Resources requested for WS-FIA activities: equipment



- Project resources were requested for building an FI testbed network in Brazil, following in the footsteps of national initiatives in other countries, such as GENI (EUA) and FIRE (UE).
- Resources conceded : ~R\$300K
- With the effective start of the project in 2010, the design for building the testbed facility was begun afresh, seeking to incorporate recent developments in appropriate technologies and application areas, in particular:
  - adoption of OpenFlow as an approach to Software Designed Networks (SDN)
  - Support for varied wireless technologies, including WiFi, WiMax and sensor networks
  - Adoption of evolving standards for developing control and monitoring frameworks (testbed automation) and federation

# Complementary activities with national funding (MCT and FUNTTEL)



- RNP and CPqD have been partners since 2002 in Project GIGA, which has built and maintains a testbed network facility in southeast Brazil, connecting more than 20 institutions, including RNP, UFF, USP (plus PUC-Rio, Unicamp, UFRJ, ...)
- In 2009, Phase 2 of Project GIGA began, directed towards FI
  - The new project testbed has adopted similar objectives and is adopting a common design with the WS-FIA testbed
  - Perspective of extending the coverage of this testbed to 24 of the 27 states in 2011, following the inauguration of RNP's new backbone network
    - This will make it possible to include UFPA and UNIFACS in an extended testbed network (also UFG, UFSCar)
  - First moves to establishing international collaboration (with the GENI project in the US)

# Testbed networks and collaboration



- Two large-scale testbed structures have been established in Brazil in recent years for support of networking and distributed applications:
  - Project GIGA testbed network
  - Project KyaTera
- These testbeds are linked nationally and internationally through
  - RNP network in Brazil
  - GLIF international collaboration in circuit services
- RNP backbone will offer circuit services to its connectors in 2011, which will permit extending testbed networks to 24 states in Brazil

# Project GIGA



- First R&D project in South America with emphasis on large-scale network experimentation
- Main objectives:
  - Development of advanced skills and scientific knowledge by participants
  - Develop Brazilian industry/service companies
- R&D focus on:
  - Optical networking
  - Current Internet services and applications
  - Future Internet architecture (from 2009)
- Funded by Funttel under Finep management
  - Phase I (2003-2007):
    - Included R&D and installation of network testbed
  - Phase II (2009 – 2012):
    - Includes R&D and some minor upgrade of the network testbed
- Collaboration between CPqD and RNP

*Future Internet Testbeds in Brazil*





# Project GIGA Testbed



- First large-scale experimental network in South America (2004)
- “Pre-deployment” large-scale lab for experimenting ideas of interest to telecom operators, service providers and RNP
- External connectivity via RNP PoPs in Rio de Janeiro and São Paulo
- 800km total fiber span over 7 cities in 2 states (SP, RJ)
- 66 labs from 26 institutions connected (fiber to the lab) at 1 and 10 Gbps
- e2e dynamic (VLAN) multidomain protected circuits for L2 and above on demand experiments

# FI: GIGA Phase 2 - FI testbed



- The original project (RNP & CPqD) was funded until 2007
- In 2009, CPqD was once more funded by Funttel, and RNP via Ministry of S&T
- In this phase focus on **Future Internet** experimentation, with active search for international partners:
  - GENI:
    - LoS provided to PrimoGeni (Spiral 2) (2009)
    - MoU for sharing connectivity with GPO (2010)
    - Informal agreement with iGENI (Spiral 2) (2010)
    - Participant in Spiral 3 proposal (2010)
  - CleanSlate Program de Stanford U (OpenFlow):
    - OpenFlow implemented on Brazilian switch (CPqD)

# GIGA Testbed : OpenFlow data plane



## OpenFlow Switch

- 24 x 10/100/1000
- 2 x 10Gb
- L2/L3
- ~2000 flow entries
- No protocol stack

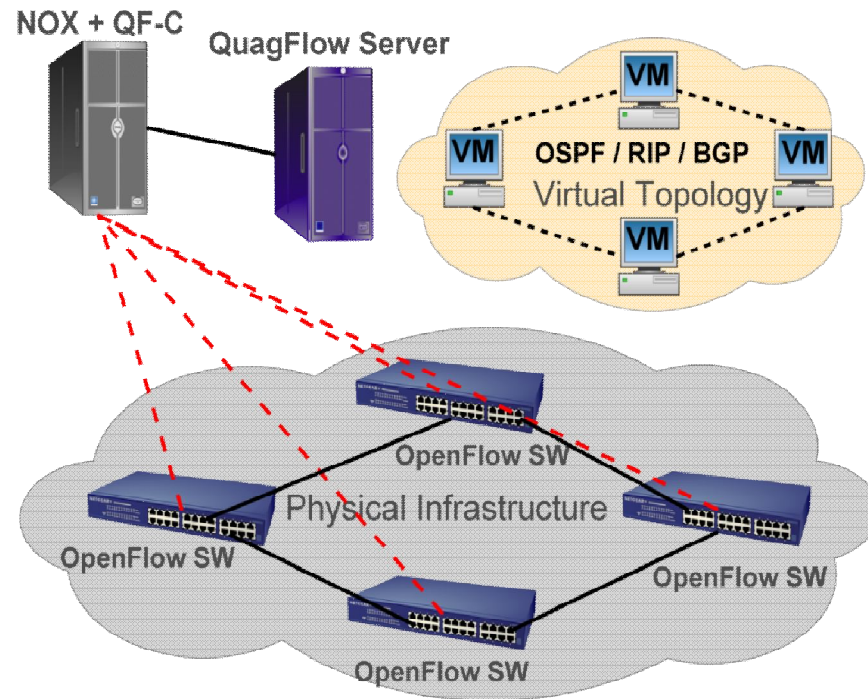
## OpenFlow ROADM

- WSS for mesh networks
- 3 / 5 degree
- Directioned / Coloured
- Virtualization-capable
- Multicast-capable



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# GIGA Testbed : Separate control plane over OpenFlow data plane



## RouteFlow:

- IP Routing stack on top of OpenFlow Controller

- Currently Quagga on top of NOX, but should work with other stacks and controllers

- Routing instances run as virtual entities in standard PC server(s)

- Currently each instance is a virtual machine, but investigating other virtualization schemes

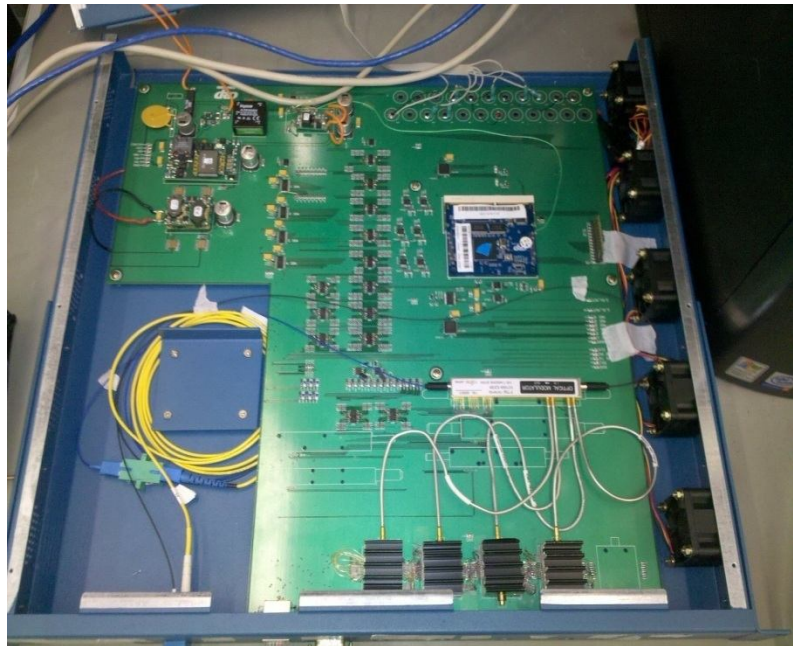
- Routing virtual entities interconnected to mimic the physical topology

- Source code available upon demand

- Approach to be taken to support GMPLS over NOX to control OF switches and ROADMs



# GIGA Testbed : 100Gb (coherent) DP-QPSK



*v1 (incomplete) prototype – Sept 2010*

**First trial (Campinas → São Paulo  
Campinas=300km) scheduled by end of 2011**

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# KyaTera research network in SP state



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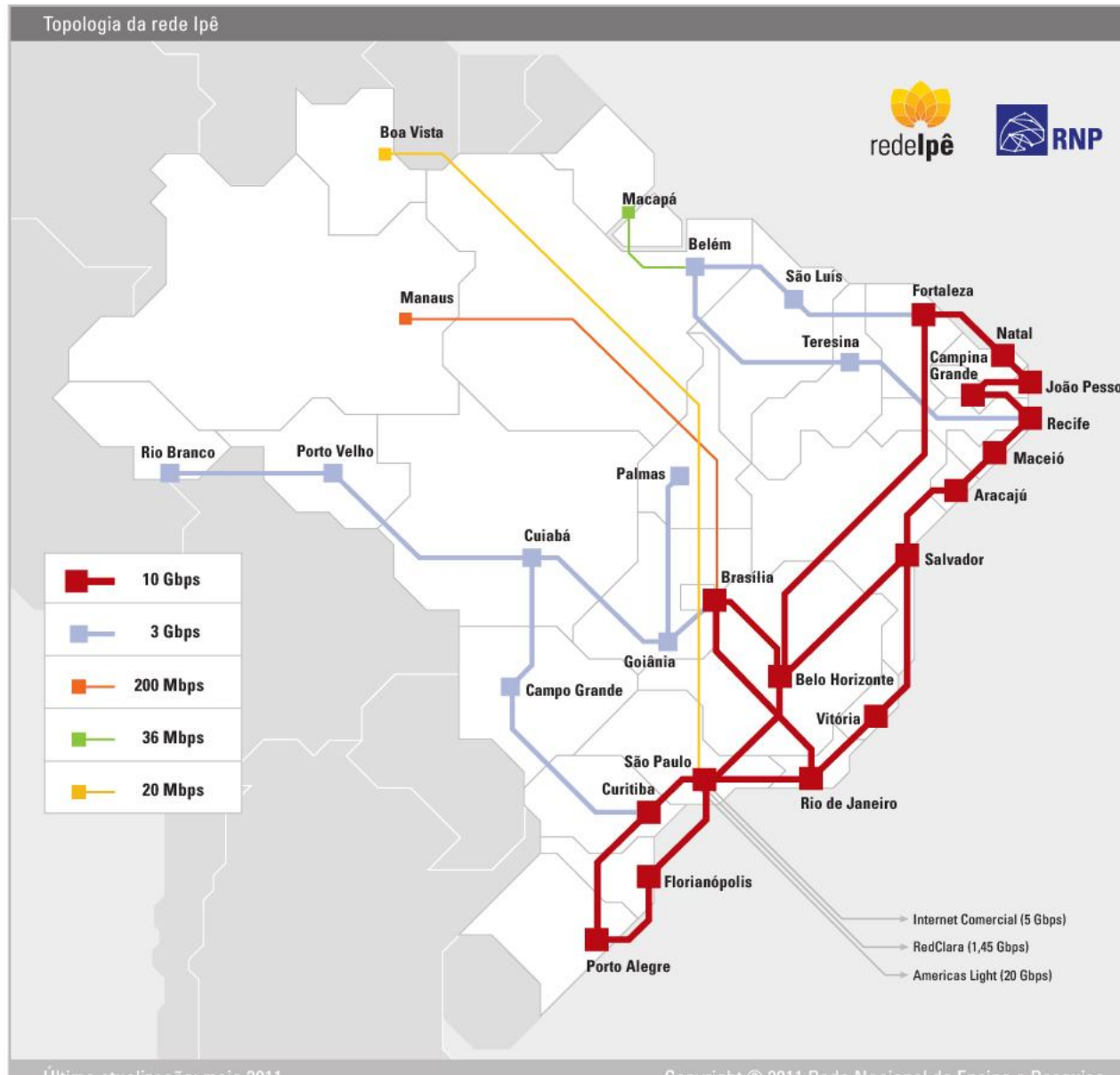


# KyaTera: details



- Dark fibre network from carrier (Telefonica)
  - 1000km total fiber span over 9 cities in SP state
  - 90 labs from 26 institutions connected (fiber to the lab) at 1 and 10 Gbps
- Layer 1 equipment (ROADM) from Padtec (Brazil)
- Layer 2 equipment (Ethernet) from Datacom (Brazil)
  - 10G channels between São Paulo, Campinas and São Carlos
  - 1G on other links
- External connections nationally (via RNP networks) and internationally via AmLight and GLIF
- Research program includes network development

# RNP infrastructure: Phase 6 national backbone in 2011



- Agreement with local telco Oi, brokered by regulatory agency
- 16 states - 10 Gbps
- 9 states - 3 Gbps
- No terrestrial fibre to other 3 states
  - North of River Amazon
  - 200Mbps to 20 Mbps
- Hybrid architecture, supporting routed IP and e2e circuit traffic





# RNP infrastructure: optical metropolitan networks



- Since 2004, RNP programme of metropolitan networks, to provide adequate access to the multigigabit backbone
- Networks are based on overprovisioned dark fiber networks, shared between the R&E institutions served
  - Usually built and owned by RNP
  - Use 1 or 10 GE transport and permit:
    - interconnection of the campi of the participating institutions
    - access to RNP's IPÊ network PoP
- 21 networks already operating
  - All 27 capital city metro networks by end 2011
- Extension underway to 14 non-capital cities – first networks to be concluded in 2011

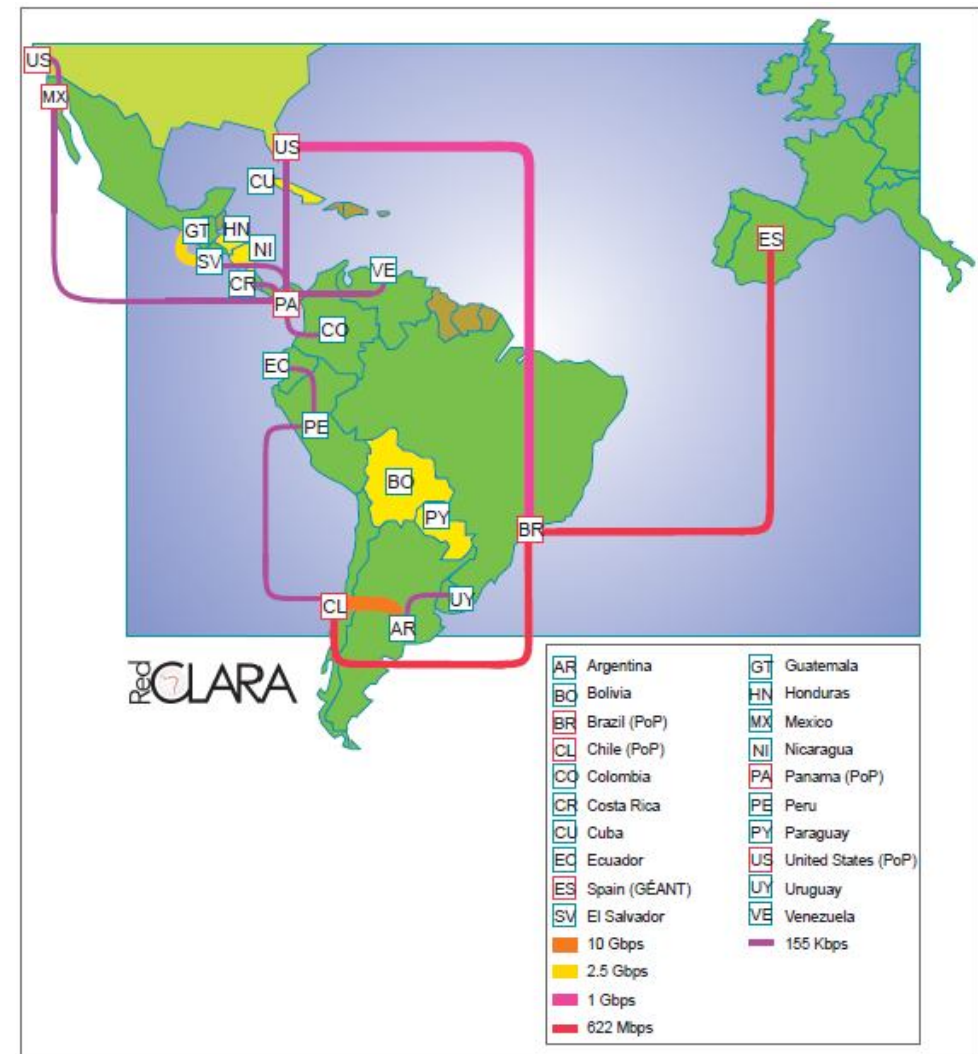
# RNP infrastructure: international connectivity



- RedCLARA: regional R&E network in Latin America
  - Created 2004 with partial funding by EU (ALICE and ALICE2 projects)
    - Currently links 13 countries in region
    - 622 Mbps Brazil-GEANT
    - Connections to US networks
- AmLight (US IRNC2 project) – RNP, FAPESP & NSF funds
  - Provides 3 links to LA networks
    - 2 cross-border dark fibre links between US and Mexico
    - 20 Gbps between US and Brazil (São Paulo)
      - Currently includes 8 Gbps commodity traffic and 1 Gbps RedCLARA
      - Also used for GLIF link to Brazil networks

# RNP infrastructure: AmLight and RedCLARA – 2011

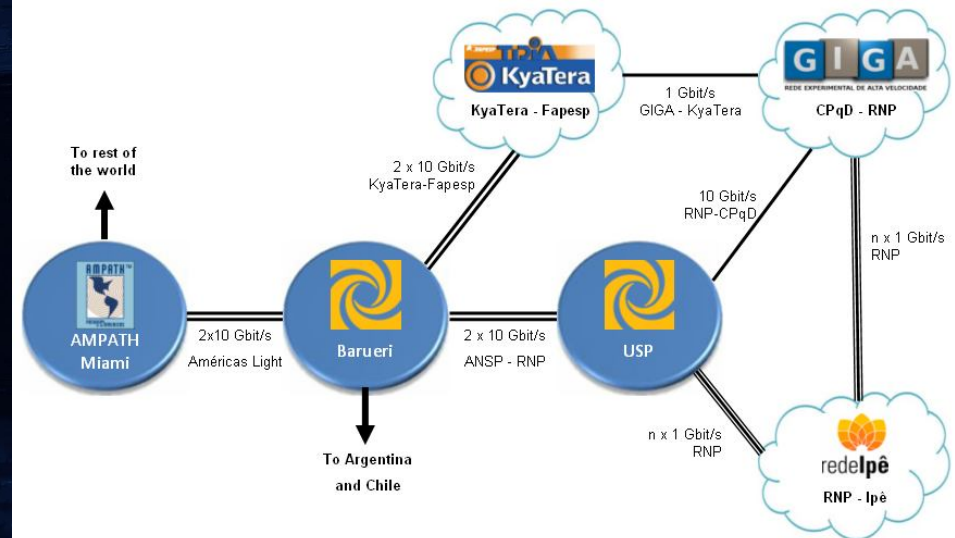
(courtesy Julio Ibarra and María José López, respectively)



Future Internet Testbeds in Brazil



# Interconnections of Experimental Networks in Brazil



Future Internet Testbeds in Brazil



# 2011: new collaboration BR-EU



- FIBRE : Future Internet Testbeds/Experimentation between Brazil and Europe
  - Brazilian partners: FIBRE-BR
    - WS-FIA: RNP, UFF, UFPA, UNIPACS, USP
    - GIGA: CPqD, UFG, UFRJ, UFSCar
  - European partners: FIBRE-EU
    - OFELIA: i2CAT (ES), U Essex (GB)
    - CHANGE: Nextworks
    - OpenLab: NICTA (AU), U Thessaly (GR), UPMC (FR)
- To be jointly funded by CNPq and EC FP7, for 30 months, starting October, 2011

# FIBRE and the Brazil-EU Coordinated Call

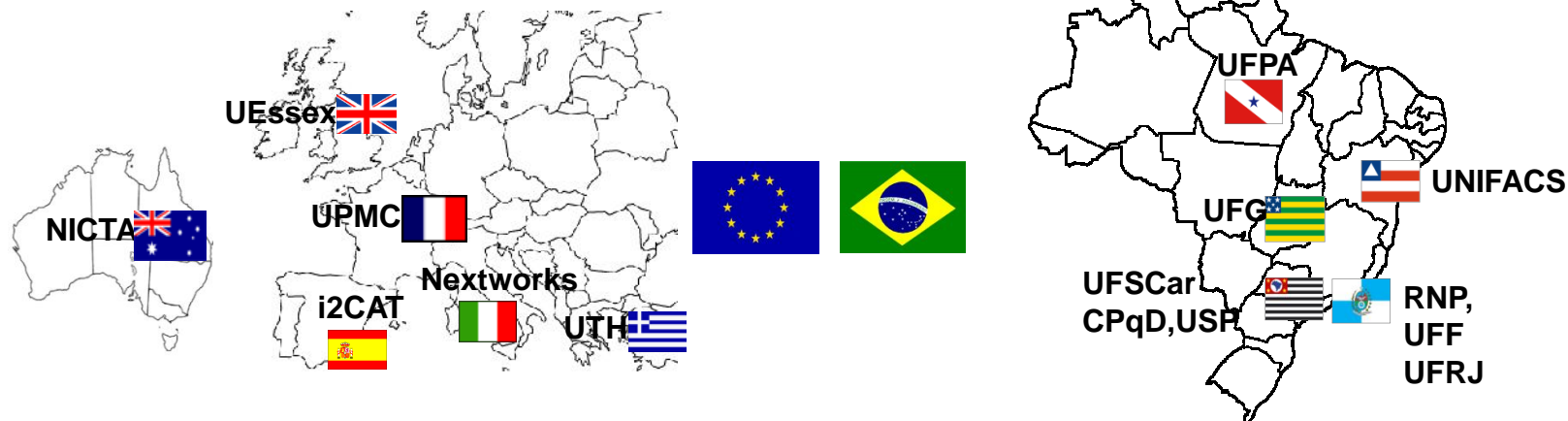
- FIBRE is one of 5 projects recently approved in the September 2010 Brazil-EU Coordinated Call for bilateral cooperation in ICT
  - 30 month projects, average budget of 1 M€ for each side
  - EU side financed through FP7, Brazil side through CNPq
  - Common workplan for the two sides of the project
- FIBRE approved in the area “Future Internet – Experimental Facilities”
- FIBRE-BR is the first large-scale Future Internet testbed project to be funded in Brazil, building on experience in smaller projects
- FIBRE-EU partners already active in current/starting FP7 FIRE projects OFELIA, CHANGE and OpenLab (successor to OneLab2)



# Project at a glance

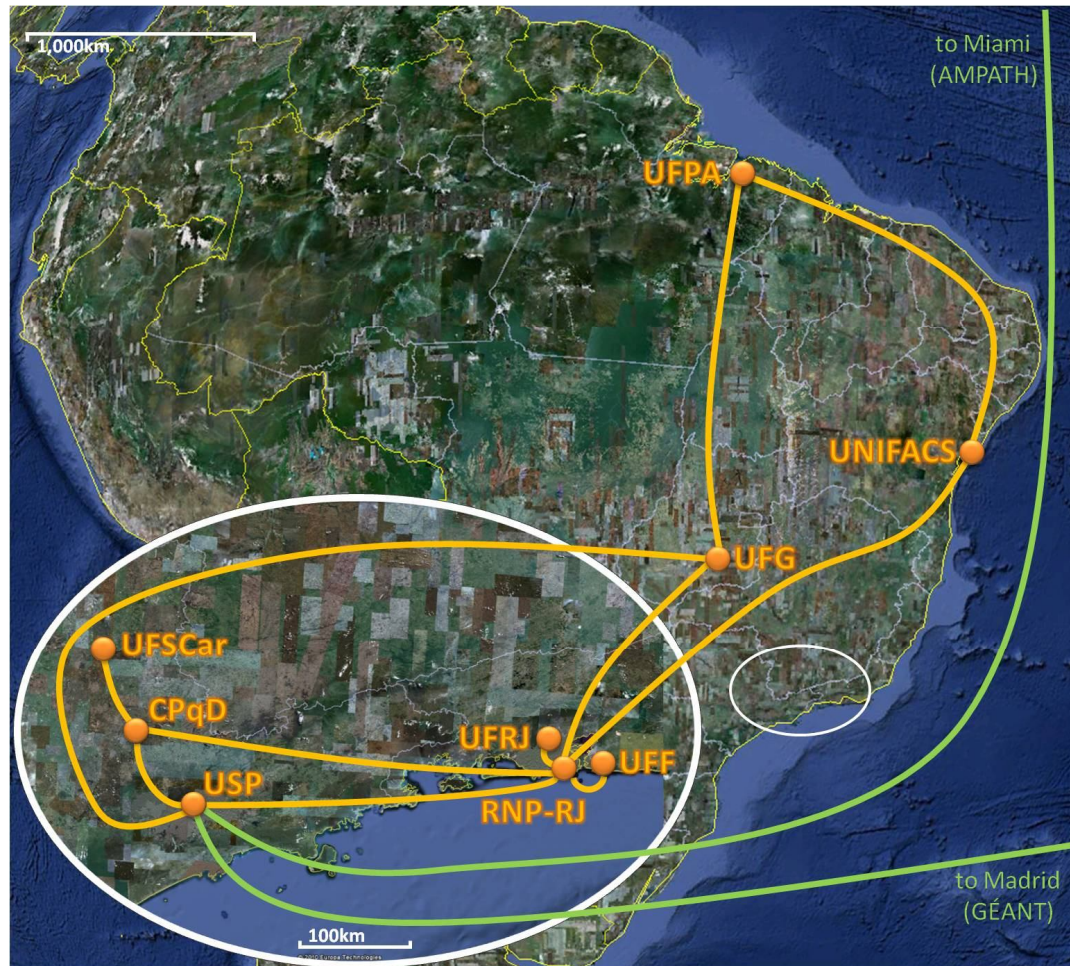
- What? Main goal
  - Create a **common space** between the **EU** and **Brazil** for **Future Internet (FI) experimental research** into **network infrastructure** and **distributed applications**, by building and operating a federated EU-Brazil Future Internet experimental facility.

- Who? 15 partners



- How? Requested to the EC ~1.1M€ and CNPq R\$ 2.3 in funding to perform 6 activities
  - WP1: Project management
  - WP2, WP3: Building and operating the Brazilian (WP2) and European (WP3) facilities
  - WP4: Federation of FIBRE-EU and FIBRE-BR facilities
  - WP5: Joint pilot experiments to showcase the potential of the federated FIBRE facility
  - WP6: Dissemination and collaboration

# The FIBRE consortium in Brazil

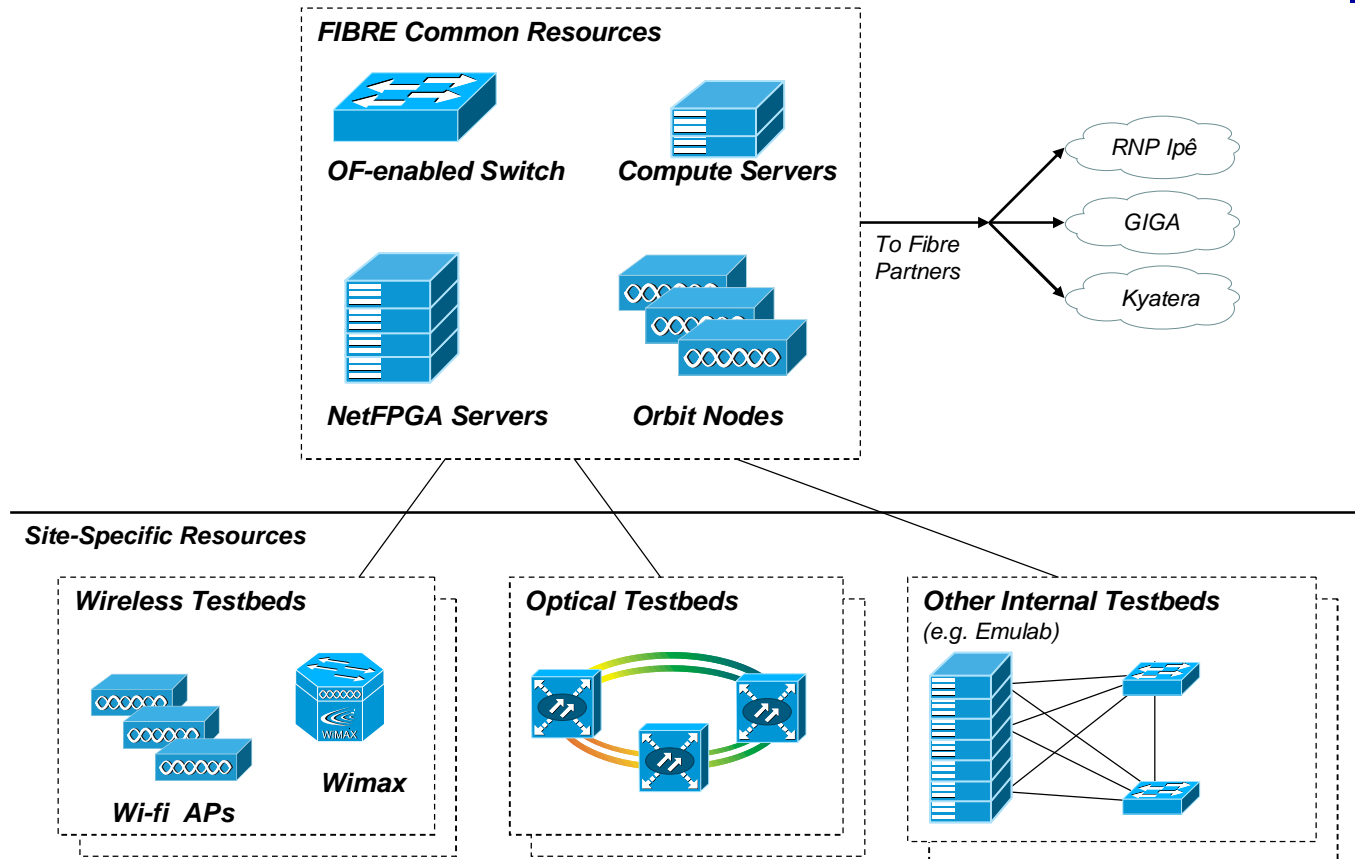


- The map shows the 9 participating Brazilian sites (islands) and the expected topology of their interconnecting private L2 network
- Possible international links are also shown.

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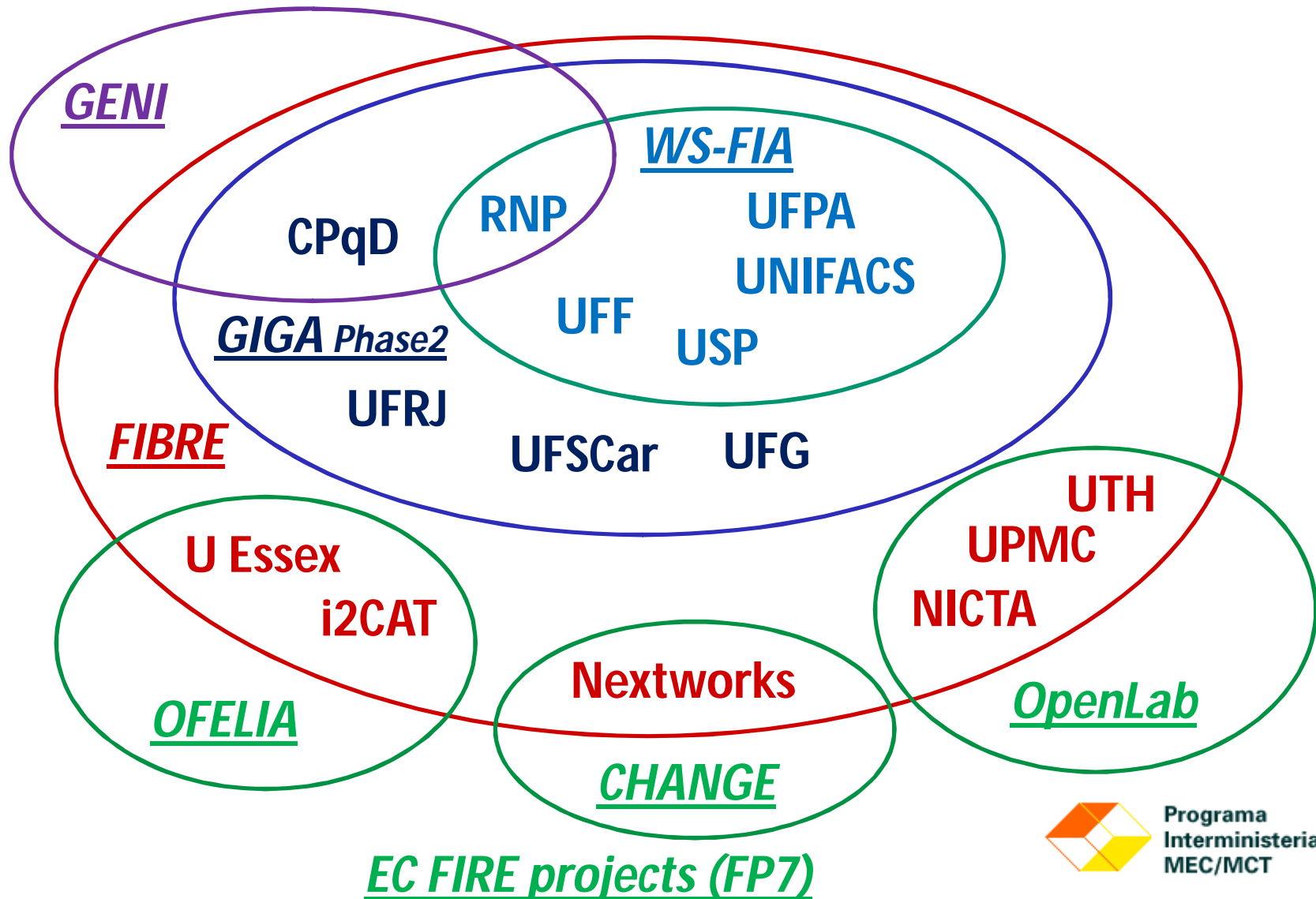


# FIBRE site in Brazil



- The figure shows site-specific resources and external connectivity

# Relationships between projects



# Perspectives



- Funding has already assured from different sources to launch a large-scale, OpenFlow-based testbed this year involving at least the Brazilian partners of the FIBRE consortium
- A slice-based FI testbed facility will be made available for the use of the Brazilian R&D community, and federation with similar initiatives in other countries will be welcomed.



## The WS-FIA team

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