FUTURE INTERNET TESTBEDS
EXPERIMENTATION BETWEEN
BRAZIL AND EUROPE

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FIBRE

Future Internet testbeds/experimentation between BRazil and Europe

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D2.1 Requirements analysis

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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)	

Abstract

The purpose of this deliverable is to define the requirements for the Brazilian Experimental Facility, also referred to here as the FIBRE-BR system, which will drive the activities to be carried out in WP2 in order to build this system from scratch. These requirements are based on two aspects: the use cases defined in the FIBRE project proposal, and the needs of Future Internet researchers in Brazil.

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1 Acronyms

aka	also known as
API	Application Programming Interface
BT	Bluetooth
CDS	Content Data Server
CN-DS	Communication Networks and/or Distributed System
CNPq	Brazil's Council for Scientific and Technological Development
CPqD	Telecommunications Research and Development Centre
EU	European Union
FI	Future Internet
FIBRE	Future Internet testbeds / experimentation between Brazil and Europe
FP7	Seventh Framework Programme
FPGA	Field Programmable Gate Array
Gbps	Gigabit bits per second
GENI	Global Environment for Network Innovations
GMPLS	Generalised MultiProtocol Label Switching
HTTP	HyperText Transfer Protocol
ICT	Information and Communication Technologies
IP	Internet Protocol
I&M	Instrumentation and Measurements
LDAP	Lightweight Directory Access Protocol
MS	Milestone
MTBF	Mean Time between Failures.
MTTR	Mean Time to Repair.
NITOS	Network Implementation Testbed using Open Source platforms
NOC	Network Operations Center
NTP	Network Time Protocol
ORBIT	Open-Access Research Testbed for Next-Generation Wireless Networks
OF	OpenFlow
OFELIA	OpenFlow in Europe: Linking Infrastructure and Applications
OGF	Open Grid Forum
OMF	cOntrol, Management and Measurement Framework
OML	ORBIT Measurement Library
ORCA	Open Resource Control Architecture
OS	Operation System
RFC	Request for Comments
RNP	National Research and Education Network
UFF	Federal Fluminense University
USP	University of São Paulo
WDM	Wavelength Division Multiplexing

Wi-Fi	Wireless Fidelity
WiMax	Worldwide Interoperability for Microwave Access
WP	Work Package
WP2	Building and operating the Brazilian facility
WP5	Development of technology pilots and showcases

2 Scope

This document is the result of the task T2.1 of WP2 of the FIBRE project. The design and implementation of the FIBRE-BR facilities, in terms of hardware and control/monitoring software will be driven by this document.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [Bradner 1997].

We classify FIBRE-BR requirements in the following categories:

- User requirements
- Use case requirements
- Architectural requirements
- Experiment Support requirements
- Instrumentation and Measurement requirements
- Infrastructure requirements
- Security requirements
- Operation requirements

In order to keep track of the requirements along the development of the projects, they are identified using the format Req XXYY, where XX identifies the category and YY the sequence number.

3 Reference Documents

[Bradner 1997] S. Bradner, “Key words for use in RFCs to Indicate Requirement Levels”, RFC 2119, March 1997.

[Falk 2007] Aaron Falk, "**GENI System Requirements Document (SRD)**," GENI Design Document 07-46, April 2007.
http://groups.geni.net/geni/attachment/wiki/OldGPGDesignDocuments/GDD-07-46.pdf

[Peterson 2007] Larry Peterson (Ed), "**GENI Facility Design**," GENI Design Document 07-44, GENI Planning Group, April 2007.
http://groups.geni.net/geni/attachment/wiki/OldGPGDesignDocuments/GDD-07-44.pdfhttp://groups.geni.net/geni/attachment/wiki/OldGPGDesignDocuments/GDD-07-44.pdf

FIBRE’s Description of Work, available under request to WP1.

[Thomas 2007] Vic Thomas, "**Lifecycle of a GENI Experiment**," Draft Recommendations, April 2009.
http://groups.geni.net/geni/attachment/wiki/ExperimentLifecycleDocument/ExperimentLifeCycle-v01.2.pdf

4 FIBRE-BR Experimental Facility overall description

The initial Brazilian facility will include new or upgraded testbeds, described below, to be installed at edge sites (aka islands) at each of the nine Brazilian partners in this project. These separate testbeds will be federated to permit experiments to use resources at multiple edge sites within Brazil, and later to extend this functionality to testbeds outside Brazil, beginning with the FIBRE-EU experimental facility in Europe. *Figure 1* shows the geographical locations of the Brazilian edge sites, of which six (including RNP headquarters) are in southeast Brazil, and one in each of the North, Northeast and Centre West regions of the country. These sites will be interconnected using private channels (Level 2) over wide area and metropolitan networks made available to the Brazilian research and education community. These include RNP's national Ipê backbone network and the GIGA testbed network, jointly maintained by RNP and CPqD. RNP-owned metropolitan networks will be used for access when necessary, and RNP international connections will provide access to other international testbeds, such as the OFELIA and NITOS testbeds, for federation purposes.

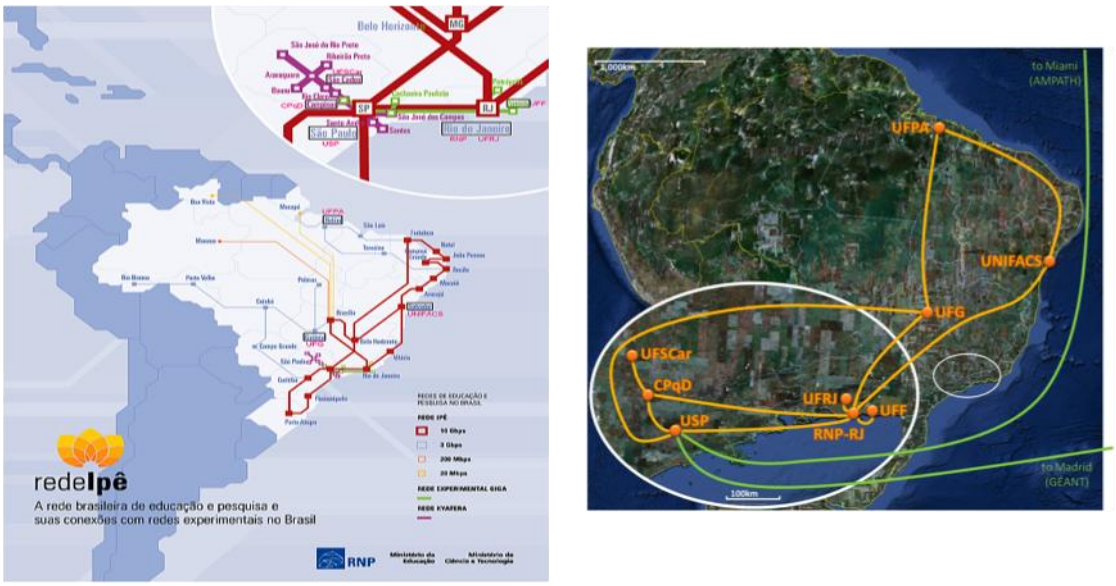

Figure 1 Location and interconnection of the initial FIBRE-BR edge sites

The FIBRE-BR facility infrastructure consists of an extensible collection of building block *components*. A given experiment carried out on the FIBRE-BR facility will use a set of such building block components, linked together to form a virtual network.

We expect the set of building block components to evolve over time as technology and research requirements advance, but we define an initial set of components to be deployed, using terminology borrowed from [Peterson 2007]:

Programmable Edge Clusters (PEC) provide the computational resources needed to build wide-area services and applications, as well as initial implementations of new network elements.

Programmable Core Nodes (PCN) implement core network data processing functions for high-speed, high volume traffic flows.

Programmable Edge Nodes (PEN) implement data forwarding functionality at the boundary between access networks and a high-speed backbone.

Programmable Wireless Nodes (PWN) implement proxies and other forwarding functionality within a wireless network.

Client Devices run applications that give end-users access to experimental services available on the combined wired/wireless substrate.

A **National Backbone Facility** provide at least 1 Gbps circuit interconnection between FIBRE-BR core nodes, forming a nationwide FIBRE-BR backbone network.

A number of **access circuits** of varying technologies connect FIBRE-BR edge sites to the FIBRE-BR core.

One or more **802.11-based Mesh Wireless Subnets** provide experimental support for ad-hoc and mesh network research based on an emerging generation of short-range radios.

One or more **Emulation Grids** that allow researchers to introduce and utilize controlled traffic and network conditions within an experimental framework.

We expect that this initial set of components will be extended in future to include some or all of the following components:

- One or more **Wide-Area 3G/WiMax-based Wireless Subnets** intended to provide open-access 3G/WiMax radios for wide area coverage, along with short-range 802.11 class radios for hotspot and hybrid service models.
- One or more **Cognitive Radio Subnets** intended to support experimental development and validation of emerging spectrum allocation, access, and negotiation models. One or more **Application-Specific Sensor Subnets** capable of supporting research on both underlying protocols and specific applications of sensor networks.

We can therefore envision the FIBRE-BR experimental facility as a nationwide backbone facility connecting a set of backbone sites, each of these is connected to edge sites that host clusters, wireless subnets, and sensor networks. *Figure 2* provides a view of a given backbone site, illustrating how the different components are connected into FIBRE-BR.

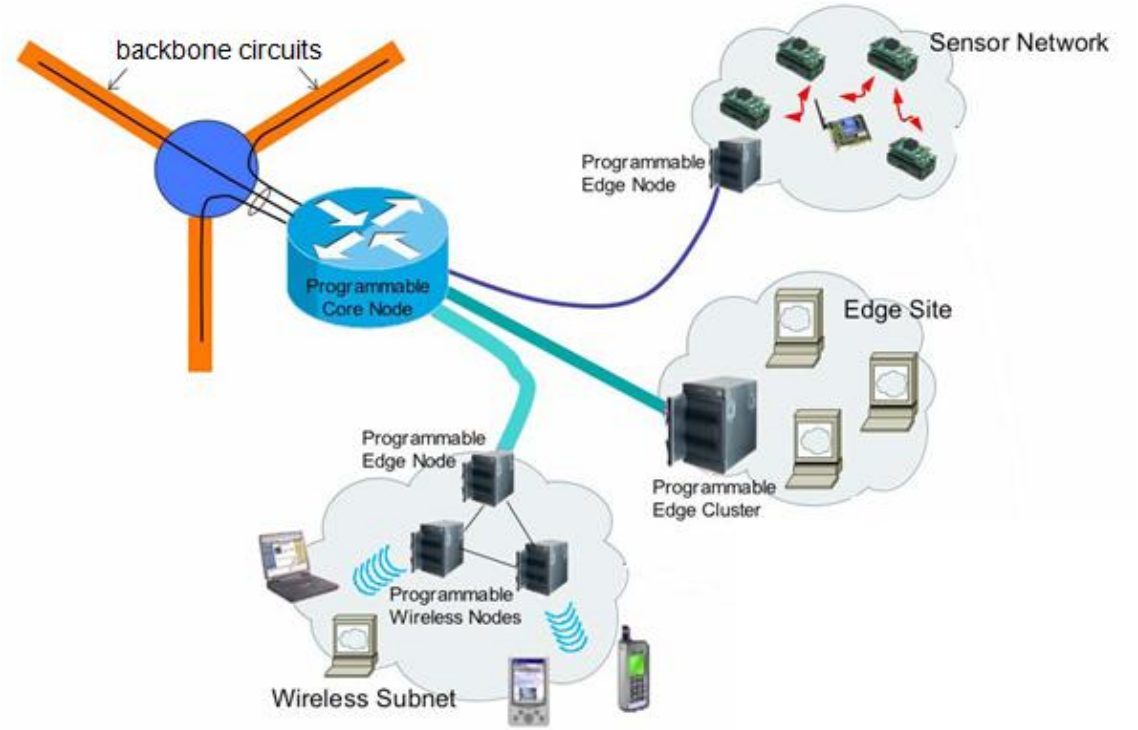

Figure 2: Backbone site perspective of FIBRE-BR components that make up the infrastructure. The PCN at the backbone Point-of-Presence is connected to edge sites via some access circuit technology (after [Peterson 2007]).

The Programmable Core Nodes and Programmable Edge Nodes of FIBRE-BR, will be based on OpenFlow technology. Each site will have a common deployment of OpenFlow-capable switches, some based on NetFPGA and others on production-quality switches, together with their controller(s), as well as a cluster of computation and storage servers, appropriately virtualised, plus a cluster of virtualised Orbit wireless nodes. Each site will propose its own possible extensions, integrating site-specific resources to FIBRE-BR, such as wireless access testbeds (WiFi, WiMax, 3G/4G), OF-enabled equipment, optical networks or even more complex testbeds with heterogeneous resources and their own control framework (e.g.: the Emulab cluster at USP [14]). *Figure 3* illustrates one FIBRE-BR site, its common facilities and examples of site-specific resources and external connectivity options.

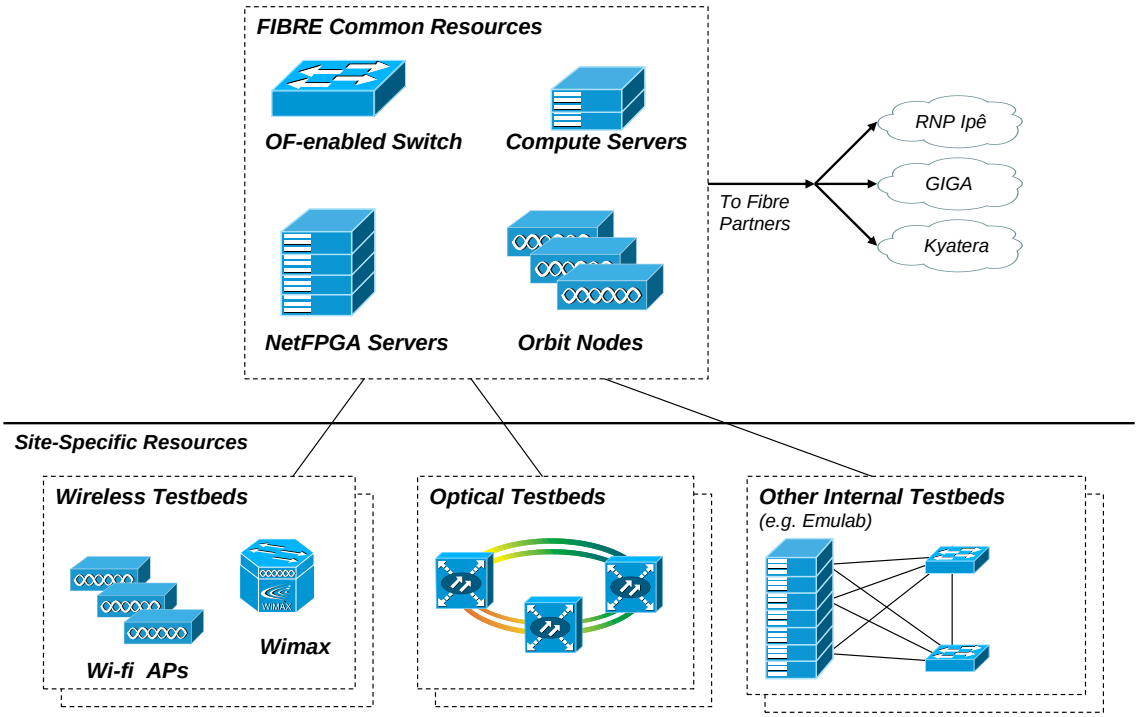

Figure 3 FIBRE-BR edge site with examples of site-specific resources and external connectivity

5 User requirements

The FIBRE-BR user is the main source of requirements for the whole system. Until FIBRE-BR is federated with international testbeds, the typical user is expected to be a researcher involved in Communication Networks and/or Distributed Systems (CN-DS). FIBRE-BR will afterwards be made available for international use, but initially, at least, only small-scale international use is forecast. In a second phase, a wider set of users is expected, potentially including any CN-DS researcher from around the world, both from academia and industry. However, this has only minor implications for the user requirements, as Brazilian research is carried out in a global context. From the first moment, the FIBRE-BR system is being prepared for federation with international platforms through the adoption of open standards.

5.1 Researcher profile

[Req UR01] The FIBRE-BR system MUST support researchers with different levels of experience, ranging from graduate students to experienced research engineers.

Discussion: This requirement will demand a documentation and support package, including tutorials, sample codes, educational materials, and helper tools.
On the other side, other sophisticated capabilities should be supported, such as advanced tools, internal system details, and low-level APIs.

5.2 Experiment lifecycle

A reference experiment lifecycle describes the conventional workflow of a FIBRE-BR experiment. Each step of this lifecycle, illustrated in Figure 4, guides the definition of the user requirements.

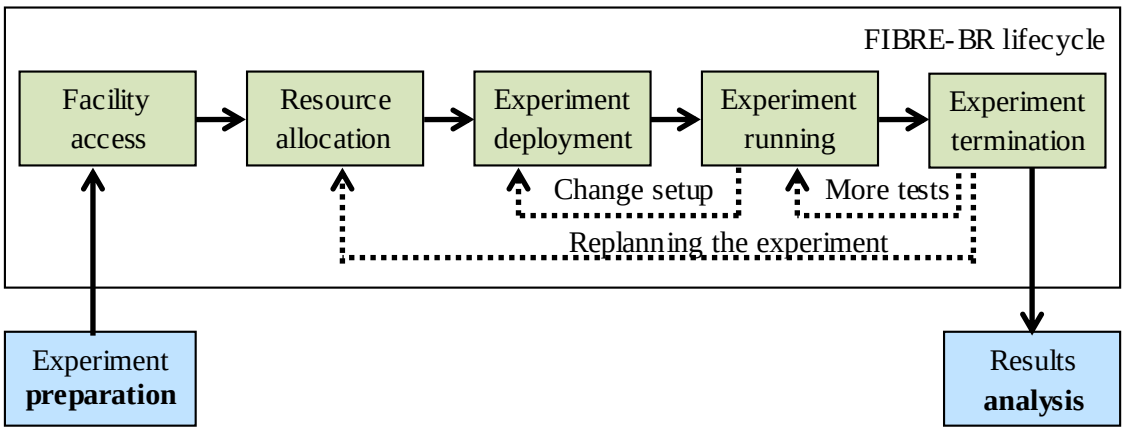

Figure 4 FIBRE-BR experiment lifecycle

The "experiment preparation" and "results analysis" are steps not included in the FIBRE-BR lifecycle, as they include tasks such as formulating hypothesis, software development to be evaluated and results evaluation.

5.3 Facility access

[Req UR02] A FIBRE-BR experimenter MUST provide their credentials to be authenticated and authorised by the system, in order to have remote access to the experimentation facilities.

Discussion: Credentials must be obtained through a registration procedure also provided by the FIBRE-BR system.

5.4 Resource allocation

[Req UR03] A FIBRE-BR experimenter MUST be able to discover available resources in the experimentation facilities, and to reserve those needed for his or her experiment, in such a manner as not to interfere unnecessarily with other experiments being carried out concurrently.

Discussion: In order to run an experiment and collect its results, the system must provide means to:

- *Find available resources (e.g.: switches, hosts (virtual or physical), wireless devices, sensors, software tools, instrumentation service, etc)*
- *Choose and reserve the resources of interest, and*
- *Define every topology for user experimentation in an exclusive manner for a specified period of time.*

5.5 Experiment deployment

[Req UR04] A FIBRE-BR experimenter MUST be able to configure the allocated resources.

Discussion: A large number of customisation options should be available, even though only a smaller set may be needed for a given experiment. The customisation items available should include hardware and software configurations, such as turning on/off some devices, installing software, changing OS parameters, choosing metrics to be collected, and choosing sampling intervas. As far as possible, these actions should be performed through a control and monitoring framework. However, a number of platform resources must be directly accessed, since no support is provided by current tools. Measurement data should be made available after experiment termination, and could help in tasks such as experiment preparation, resource allocation, etc. Infrastructure measurement data will be made available to all users, while experiment measurement data could be shared if so desired, on a case to case basis.

5.6 Experiment running

[Req UR05] During the period reserved for an experiment, a FIBRE-BR experimenter MUST be able to start, pause, stop or reset an experiment at any given moment.

[Req UR06] An experimenter MUST have full control over the experiment running.

[Req UR07] An experimenter or the facility operator MUST be able to terminate an experiment that, due to mal-function, is affecting negatively the performance or behaviour of other experiments or even of the facility as a whole.
Discussion: This action must extend to all affected facilities, and may lead to the release of all resources allocated to that experiment.

[Req UR08] The system SHOULD enable an experimenter to change the configuration of the allocated resources, moving back to a previous snapshot of the "experiment deployment".

[Req UR09] Taking into consideration the resource limits defined in step "resources allocation", the experimenter MUST also be able to grow or shrink the elements involved in the experiment.

5.7 Experiment termination

[Req UR10] A FIBRE-BR experimenter MUST be able to archive the experiment setup and its results, in order to permit post-mortem analysis.

[Req UR11] Experiment archives SHOULD be made available for other experimenters to validate, re-run, and make comparisons.

[Req UR12] An experiment archive MUST include a human-readable description of the experiment, as well as setup information, experiment results and any special considerations for repeating the experiment.

[Req UR13] An experiment archive SHOULD also include the experiment description in a formal language.

5.8 Support service

[Req UR14] A FIBRE-BR experimenter MUST have access to FIBRE-BR usage guidelines, and to a communication channel to report problems.
Discussion: Basic procedures and examples of their use are important to facilitate the adoption of the system. Problems may occur and should be reported to a support entity using the communication channel, e.g.: a mailing list, a ticketing system.

6 Use case requirements

6.1 Introduction

FIBRE-BR MUST support the following three Use Cases defined in the FIBRE project proposal:

- Use Case 1 - **Seamless Mobility for Educational Laptops** - targets mobile wireless experiments and applications, and has, in addition to the common OpenFlow enabler and WiFi access point providing spatial coverage for experimental wireless communication, laptops and/or programmable handheld devices with WiFi and Bluetooth (BT) interfaces, plus instrumentation for traffic generation and analysis and mobility emulation. At least one facility of type 1 also includes a WiMAX base station and various multi-interface laptops and/or handheld devices (WiMAX, WiFi and BT enabled)
- Use Case 2 - **High definition content delivery across different sites** - targets wired networking experiments and applications and has a multicast-enabled optical reconfigurable WDM infrastructure plus content server(s) to stream high definition video and a projection system to display high definition streams
- Use Case 3 - **Bandwidth on Demand through OpenFlow GMPLS in the FIBRE facility** - enhances Use Case 2 with a GMPLS control plane that is capable of, in an integrated way, dynamically reconfiguring the whole network to optimize use of resources and user experience upon the need to redirect users from one content delivery server to another.

6.2 Use Case 1 requirements

In order to run experiments defined in Use Case 1, the FIBRE-BR system requirements are detailed below.

6.2.1 Specifics components

[Req UC01] The FIBRE-BR system MUST support the following components:

- Content sever
- OpenFlow Switch
- WiMax base station
- Orbit nodes
- OpenFlow-compatible Nodes
- GPS nodes

6.2.2 Environmental Monitoring

[Req UC02] The FIBRE-BR system SHOULD support the export to the experimenter of the physical properties of RF channels, such as signal-to-noise relation or interference conditions near nodes, , when available.

Discussion: Monitoring of the physical properties of RF channels will not be provided by all islands.

6.2.3 Handoff issues

A vertical handoff is said to occur, when a network node switches from one supporting infrastructure (e.g. wireless LAN) to another (e.g. WiMax). Therefore, it refers to the automatic failover from one technology to another, in order to maintain communication.

[Req UC03] The FIBRE-BR testbed MUST provide the means for researchers to investigate all issues involved vertical handoffs.

[Req UC04] To allow for investigation into vertical handoffs, nodes involved (laptops or smartphones) MUST possess two or more interface types, such as WiFi, WiMax, GSM, etc.

6.2.4 Customised reports

[Req UC05] Some predefined report templates, based on the experiment type, SHOULD be provided. The FIBRE-BR system MAY also provide the means to generate customised reports based on the selection of some of the metrics made available in the experiment logs.

6.2.5 User profiles

[Req UC06] The FIBRE-BR system SHOULD allow user profile data to be exported and/or shared, so that the parameters already selected can be imported by any other user of the environment, subject to the owner's permission.

6.3 Use Case 2 requirements

In order to run experiments defined in Use Case 2, the FIBRE-BR system requirements are detailed below.

6.3.1 Specific components

[Req UC07] The FIBRE-BR system MUST support the following components:

- OpenFlow switches
- Dynamically-reconfigurable WDM equipment with OpenFlow support
- Content delivery server to store HD and 4K quality media
- Content delivery application to control delivery of streams to subscribers

- 4K projection facility to display 4K-quality media streaming that is compatible with the FIBRE UK island´s projection facility
- HDTV to display HD-quality media streams

6.3.2 Experiment storage requirements

[Req UC08] The FIBRE-BR system MUST provide enough capacity to store 4K experiment data, i.e. 3 or 4 4K-videos (~ 5TB).

6.3.3 Physical infrastructure

[Req UC09] The participating FIBRE-BR island in this use case MUST provide energy, air conditioning, cabling, racks, floor space and physical security to host servers, projectors and communications equipment.

6.3.4 Connectivity

[Req UC10] In order to participate in this Use Case, FIBRE islands in EU and in BR MUST be interconnected by high performance network links. More specifically, content delivery servers MUST be connected, and it MUST be possible to connect any user with one or another content delivery server at a time.

6.4 Use Case 3 requirements

Use Case 3 builds on Use Case 2 and, as such, inherits all of its requirements. Thus, for Use Case 3 the FIBRE-BR system requirements are detailed below.

6.4.1 Specific components

[Req UC11] In order to run experiments defined in Use Case 3, the participating FIBRE-BR island MUST deploy a GMPLS Stack as a NOX application, in order to be able dynamically to reconfigure the switching elements to redirect users from one server to another, according to criteria to be defined on demand.

7 Architectural requirements

7.1 Federation

[Req AR01] The FIBRE-BR architecture MUST enable federation, which is the management and inter-operation of multiple independently administered resources, referred to here as islands, which are owned by multiple distinct organisations both participating in the FIBRE project and external to it, and possibly using different wired and wireless technologies.

7.1.1 Inter-Organization Communication

[Req AR02] The FIBRE-BR system SHALL provide a framework for the communication among federated organizations, which enables the inter-operation of the Brazilian and European islands, as well as with other external testbeds.

7.1.2 Authentication Management and Access Control

[Req AR03] The FIBRE-BR system SHALL provide the means to enable organizations to carry out secure authentication of users from federated organizations, possibly providing different levels of clearance and access according to organization policies and the needs of the users.

7.1.3 Federation Management

[Req AR04] The FIBRE-BR system SHALL allow administrators to manage the federation. This involves activities such as including new islands, installing and updating system federation software, and monitoring the federation in terms of performance, functionality, and security.

7.1.4 Resource Description

[Req AR05] The FIBRE-BR system SHALL allow federated organizations to describe resources that they contribute to the federation in a common format.

[Req AR06] The adopted format SHOULD be flexible enough to permit the description of resources from different technologies.

7.1.5 Resource Allocation

[Req AR07] The FIBRE-BR system SHALL provide mechanisms to allocate resources between experiments being run concurrently.

7.1.6 Resource Sharing

[Req AR08] The FIBRE-BR system SHALL provide mechanisms to enforce resource sharing policies between experiments being run concurrently.

7.1.7 Usage Policy

[Req AR09] The FIBRE-BR system SHALL allow federated organizations to declare usage policies for substrate facilities under their control, and to provide mechanisms for enforcing those policies.

7.1.8 Resource Allocation Portal

[Req AR10] The FIBRE-BR system SHALL include a portal that allows experimenters to acquire, schedule, and release federated resources.

7.1.9 Open Interfaces

[Req AR11] The FIBRE-BR system SHALL offer access to the federated resources through open interfaces.

7.1.10 Measurements and Experimental Results Integration

[Req AR12] The FIBRE-BR system SHALL provide a framework for gathering measurements and results from experiments run across multiple federated resources.

7.1.11 Technology Heterogeneity and Extensibility

[Req AR13] The FIBRE-BR system SHALL federate different experimental facilities and technologies and, additionally, be extensible enough to support future technologies still to be developed.

7.2 Sliceability and Programmability

7.2.1 Programmability

Programmability requirements on the FIBRE-BR system seek to exploit advanced software techniques and technologies in order to make network infrastructure more flexible, thereby allowing researchers and users to customize network elements to meet their own specific needs (when possible).

[Req AR12] The FIBRE-BR system MUST provide customisable mechanisms for routing, signalling, resource allocation and the acceleration of information processing.

Discussion: In this manner, security, reliability and performance issues attain higher significance. A number of important innovations are creating a paradigm shift in networking, which leads to higher levels of network programmability. These include:

- *Availability of open programmable network interfaces.*
- *Separation between transmission hardware and control software.*
- *Accelerated virtualization of network infrastructure.*
- *Rapid creation and deployment of new network services and architectures.*
- *Environments for resource partitioning and coexistence of multiple distinct network architectures.*
- *APIs for different programming languages, allowing total control over the (virtual) network.*

7.2.2 Sliceability

The FIBRE-BR system uses sliceability requirements to allow multiple experiments and share physical resources in the network. Sliceability requirements are applicable only in the use cases, following the requirements below:

7.2.2.1 Slice management tools

[Req AR13] The FIBRE-BR system MUST provide tools for configuring, managing, monitoring and debugging end-to-end slices.

7.2.2.2 Slice data containment

[Req AR14] The FIBRE-BR system MUST include a means for providing isolation between slices (except when the slices share resources), in order to ensure that independent experiments do not interfere with one another.

7.2.2.3 Slice resource isolation

[Req AR15] These isolation mechanisms MAY vary for different types of experiments.

[Req AR16] These isolation mechanisms MUST be sufficiently robust to make reproducible experiments possible.

[Req AR17] A user MUST be able to assess the level of isolation of his slice, and the degree of interference caused by other slices.

7.2.2.4 Growing and shrinking slices

[Req AR18] The FIBRE-BR system MUST provide mechanisms to control resources, such as adding resources to and/or subtracting them from an existing slice, in order to grow or shrink a long-lived experiment.

[Req AR19] Thus, the researcher MUST NOT be forced to tear down and re-create a slice, in order to make changes to its configuration.

7.2.2.5 Slice composition

[Req AR20] The FIBRE-BR system MUST support controlled interconnection of slices to each other and to external networks, such as the current Internet.

7.2.3 Technology Heterogeneity and Evolution

The following requirements present the high-level objectives of the research enabled by FIBRE-BR, in terms of technology heterogeneity and future technology insertion.

7.2.3.1 Network measurement and monitoring

[Req AR21] The FIBRE-BR system MUST provide integrated monitoring and measurement capabilities across all provided facilities.

7.2.3.2 Heterogeneous physical layer technologies

[Req AR22] The FIBRE-BR system MUST support wired, optical and wireless environments and interconnections between them.

7.2.3.3 Integrated resource management

[Req AR23] The FIBRE-BR system MUST provide integrated resource management (reservation, announcement and discovery) for all provided facilities.

7.2.3.4 Multi-technology wireless networks

[Req AR24] The FIBRE-BR system MUST provide support for multiple wireless technologies (e.g. Ad-Hoc, Wi-Fi, WiMax, Bluetooth, etc.).

7.2.3.5 Seamless connectivity

[Req AR25] The FIBRE-BR system MUST support horizontal and/or vertical handover in wireless facilities.

7.2.3.6 Future technology insertion

[Req AR26] The FIBRE-BR system MUST provide explicitly defined and extensible system interfaces to facilitate the incorporation of additional technologies.

8 Experiment Support requirements

The FIBRE-BR system should support experiments in many fundamental ways. In this section, we will identify several types of tools, services and features that need to be supported in order to ease the burden on an entry-level researcher carrying out experiments.

First, for clarification, we define an Experiment as a proper and fair use of allocated resources from the FIBRE-BR system, by an authenticated experimenter, in the context of a previously defined slice that could use network resources from multiple FIBRE-BR and FIBRE-EU islands. We anticipate it will be necessary to define an Acceptable Use Policy (AUP), as may be deduced from Sections 7.1.3 to 7.1.7, as applied at the federation level.

Such an Experiment could be further classified according to its duration (short-lived to long-lived), the total amount of resources allocated (small or massive) and the homo/heterogeneity of resources involved. We envision 3 main areas of requirements for support of Experiments.

8.1 Experiment Management

According to section 5.2, the Experiment lifecycle has 3 sub-phases specifically related to the deployment, running and termination of experiments. Thus, it is important to focus on building tools to ease these tasks for the researcher.

8.1.1 Experiment Deployment

[Req ES01] The FIBRE-BR system MUST provide the basic tools to distribute and/or install experimental code and data over every island.
Discussion: The researcher, while in the management plane, using a secure channel, should have easy access to tools remotely to synchronise file system directories. It would also be desirable in the long run remotely and easily to install standard software packages in several machines at once, and to create a number of virtual machine bundles to be started anywhere in any quantity.

8.1.2 Running Experiments

[Req ES02] The FIBRE-BR system MUST provide a basic interface for the experimenter to be able to check the status of his experiment.

Discussion: A portal, already described previously, would be the place to present this information regarding the status of an experiment.

[Req ES03] The FIBRE-BR system MUST provide a basic lightweight mechanism to monitor experiment misbehaviour and trigger instant alarms in case of problems.

Discussion: It would be desirable in the long run, for the FIBRE-BR system to have some type of autonomic feature that could perform internal, undisruptive and controlled measurements to assess if any experiment is out of control. In that case, it must inform this immediately to the facility operator and to the experimenter, and, as a last resort, when this misbehaviour is not controlled neither by the operator, nor by the experimenter, the system itself must shut it down.

8.1.3 Experiment termination

s

[Req ES04] The FIBRE-BR system MUST provide a basic method for terminating an experiment, either by using timers or a stop button, and the system MUST provide clean-up routines to release facility resources allocated to an experiment.
Discussion: This could be done by monitoring the creation of processes by an experiment and logging their identifiers for later use to stop them, by killing the processes. In addition, the system must provide a way to terminate an experiment after a specified time, thus it would be desirable to have a carefully timed machine running NTP to be the timeout service master.

8.2 Experiment Accountability

[Req ES05] The FIBRE-BR system MUST make an experiment accountable for any misuse of resources.
Discussion: In the FIBRE-BR system, different types of researchers might be able to generate experiments of different characteristics and be responsible for them. There might be several ways for the system to support this accountability; it could be either by supporting LDAP authentication and log reporting on every access related to an experiment. It would be desirable that the LDAP itself have different account levels depending on trust, seniority, funding, and different logging levels in order to help the accountability of a misuse of the facility.

8.3 Experimental Realism & Control

[Req ES06] The FIBRE-BR system SHOULD provide support for experimental realism. This implies adding support to automatic tools and features that make the environment more realistic and repeatable.

8.3.1 Repeatability

[Req ES07] The FIBRE-BR system SHOULD support repeatable behaviour for any selected experiment.

Discussion: A possible way to accomplish this would be a full integration of tools that allow the capture and later replay of packets in exactly the same temporal order that they arrive, either in the control plane, management plane or data plane. In the case of the data plane, it might be impossible to collect data at line rate from high speed devices due to differences in network speeds and remote disks. Thus, other features could be planned for the future, such as packet payload-stripping mirror ports.

8.3.2 Intentional Failure and/or Degradation

[Req ES08] The FIBRE-BR system MUST provide a basic mechanism to support intentional degradation of some components. *Discussion: The FIBRE-BR system could make extensive use of network emulation associated with interfaces, machines or virtual machines in order to create adverse environments that could reproduce real conditions of packet loss and outages. In respect to wireless islands, in the future, it could be desirable to acquire jamming generators to improve the realism of the wireless facility.*

8.3.3 Virtualizing Management Interfaces

[Req ES09] The FIBRE-BR system MUST provide support for a virtualized management plane, separate from the data plane, which could be used by system operators for low-level monitoring of experiment resources in any phase.
Discussion: The management plane is something that could be virtualized as well, using the same slicing subsystems, as the slices are virtualized and independent. This could foster research in the area of network operation and management.

8.3.4 Realistic Background Traffic

[Req ES10] The FIBRE-BR system MUST provide a broad range of realistic background traffic to be added to the experiment at any time.
Discussion: Using virtual machines across the multiple FIBRE-BR islands, and preparing in advance virtual machine bundles with pre-installed software, such as an IP traffic generator, video servers, automatic HTTP benchmarks, on-off generators, and so on. The FIBRE-BR system could support these by adding (by means of scripting or other cloud middleware) servers to the experiment.

9 Instrumentation and Measurement requirements

9.1 Definitions:

Substrate – typically, substrates are comprised of servers, switches (OF-enabled or not), routers and wireless devices.

9.2 Instrumentation and Measurements Requirements

[Req IM01] The FIBRE-BR experimental facility MUST include an Instrumentation and Measurement (I&M) subsystem in order to provide data gathering, analysis, and archival capabilities to network operators, experimenters and island administrators in a federated environment.

9.2.1 Substrate Measurements

[Req IM02] The FIBRE-BR I&M subsystem MUST provide performance and operational measurements, including power usage, of the physical equipment, which provides support to the FIBRE-BR system itself.
Discussion: Mechanisms to alert and alarm about eventual component outages must be provided.

9.2.2 Experiment Measurements

[Req IM03] The FIBRE-BR I&M subsystem MUST provide a monitoring interface for experiments.

9.2.3 Privacy of Measured Data

[Req IM04] The FIBRE-BR I&M subsystem SHALL implement a mechanism to protect its measured data as defined by the FIBRE-BR access policy.
Discussion: The FIBRE-BR access policy must be defined during project execution.

9.2.4 Link Measurements

[Req IM05] Besides the equipment that is part of the substrate, optical, wired and wireless links SHOULD be monitored.

9.2.5 Measurement Data Transmission and Storage

[Req IM06] The FIBRE-BR I&M subsystem MUST allow measured data to be collected and stored.

9.2.6 Component Locations

[Req IM07] The physical location of the FIBRE-BR components SHOULD be informed to the users.

9.2.7 Time Services

[Req IM08] Time synchronization is essential for any measurement infrastructure. Ideally, accuracy in the order of microseconds SHOULD be provided. However, due to cost concerns, in some components accuracy in the order of milliseconds can be tolerated.

9.2.8 Federation

[Req IM09] The FIBRE-BR I&M subsystem SHALL support integration among wired and wireless islands, and SHOULD support integration with external I&M infrastructuresand.

10 Infrastructure requirements

The infrastructure requirements in this section use the definitions of the description of the FIBRE-BR Experimental Facility design in section 4.

10.1 Infrastructure components requirements.

[Req IF01] The FIBRE-BR facility MUST include a collection of building block components permitting the creation of virtual networks.

10.1.1 Expansibility.

[Req IF02] The FIBRE-BR infrastructure MUST be expansible, permitting new components to be added after facility construction.

10.1.2 Computational Resources for Services.

[Req IF03] The infrastructure MUST include the computational resources necessary to build wide-area services and applications, as well as initial implementation of new network elements.

10.1.3 Programmable Core Nodes (PCN).

[Req IF04] The infrastructure SHOULD include core network data processing functions for high-speed, high-volume traffic flows.

10.1.4 Programmable Edge Nodes (PEN).

[Req IF05] The infrastructure MUST include data forwarding functionality at the boundary between access networks and a high-speed backbone.

10.1.5 Programmable Wireless Nodes (PWN).

[Req IF06] The infrastructure MUST include proxies and other forwarding functionality within a wireless network.

10.1.6 Mobile Devices.

[Req IF07] The infrastructure MUST include mobile devices intended to run applications that give end-users access to experimental services available on the combined wired/wireless substrate.

10.1.7 National Backbone Facility.

[Req IF08] The infrastructure MUST include lightpath interconnection between FIBRE-BR core nodes, forming a nationwide backbone network supporting rates of at least 1 Gbps.

10.1.8 Edge-to-Core Access Circuits.

[Req IF09] The infrastructure MUST include access circuits to connect FIBRE-BR Edge Sites to the FIBRE-BR Core, supporting rates of at least 1 Gbps.

10.1.9 802.11-based Mesh Wireless Subnets.

[Req IF10] The infrastructure MUST include at least one 802.11-based mesh wireless subnet to provide real-world experimental support for ad-hoc and mesh network research based on an emerging generation of short-range radios.

10.2 Wide-Area 3G/WiMax-based Wireless Subnets.

[Req IF11] The infrastructure SHOULD include at least one Wide-Area 3G/WiMax-based Wireless Subnet intended to provide open-access 3G/WiMax radios for wide area coverage, along with short-range 802.11 class radios for hotspot and hybrid service models.

10.2.1 Cognitive Radio Subnets.

[Req IF12] The infrastructure SHOULD include at least one cognitive radio subnet intended to support experimental development and validation of emerging spectrum allocation, access, and negotiation models.

10.2.2 Sensor Subnets.

[Req IF13] The infrastructure SHOULD include at least one Application-Specific Sensor Subnet capable of supporting research on both underlying protocols and specific applications of sensor networks.

10.2.3 Emulation Grids.

[Req IF14] The infrastructure MUST include at least one Emulation Grid that allow researchers to introduce and utilize controlled traffic and network conditions within an experimental framework.

10.3 Infrastructure physical requirements

The requirements that an institution MUST support in order to participate in the FIBRE-BR facilities as:

10.3.1 Physical space, energy and air conditioning

[Req IF15] The institution MUST support enough space for at least one FIBRE-BR rack with the components described above. These racks MUST be energized and air conditioned according to project requirements.

10.3.2 Network access requirements

[Req IF16] The institution MUST provide a dedicated access link to the experimental facilities in order not to create disturbances in the production network.

11 Security Requirements

The security requirements are divided in three categories, which are described in this section:

1. the complete FIBRE-BR system composed by all experimental facilities;
2. the interconnection between FIBRE-BR experimental facilities;
3. the interconnection between FIBRE-BR system and the Internet.

11.1 FIBRE-BR System:

[Req SE01] All participating experimental facilities MUST adopt and maintain the security best practices for networking, operating systems, and applications provided by FIBRE Project.

[Req SE02] The FIBRE-BR system SHALL only assign an identity to a user that was approved in a defined registration process.

[Req SE03] All components, institutions, researchers, and slices MUST be assigned a unique identity.

[Req SE04] The FIBRE-BR system MUST require user compliance with the defined authentication and authorisation policies before the resource allocation.

[Req SE05] The FIBRE-BR system MUST permit system activity to be audited and traced back to the responsible entity.

[Req SE06] The FIBRE-BR system MUST provide the least privilege to each component of the system in order to grant exactly the privileges it needs to perform its tasks and no more.

[Req SE07] The FIBRE-BR system MUST provide access control mechanisms to ensure that resources are only granted to those users who are entitled to them.

[Req SE08] The FIBRE-BR system MUST provide mechanisms to establish secure communications between system entities.

[Req SE09] The FIBRE-BR system MUST ensure integrity and availability of the experimenters' data during the lifespan of the experience.

[Req SE10] The FIBRE-BR system MUST isolate slices from each other, so that a sliver cannot access objects (e.g., files, ports, processes) or eavesdrop network traffic from another slice, without permission.

[Req SE11] The FIBRE-BR system MUST isolate slices from the experimental facility infrastructure, so that a slice cannot compromise facility operation.

11.2 Interconnection among FIBRE-BR experimental facilities:

[Req SE12] The FIBRE-BR system MUST provide mechanisms to establish trust relationships between system entities.
[Req SE13] The FIBRE-BR system MUST support authorisation and access control of users from other experimental facilities.
[Req SE14] The FIBRE-BR system MUST provide mechanisms to guarantee that only authorised traffic is allowed among experimental facilities.

11.3 Interconnection between FIBRE-BR and the Internet:

[Req SE15] The FIBRE-BR system MUST provide control mechanisms for inbound/outbound traffic, in order to prevent attacks and/or unauthorized access from/to the Internet.

12 Operations requirements

12.1 Support Structure

[Req OP01] The FIBRE-BR system MUST be supported by a minimum support infrastructure.

It is envisioned to have different levels of support to ensure service operations of the islands and its connection.

[Req OP02] The FIBRE-BR system MUST at least offers 3 levels of support:

- Level 1
  To be provided by a centralized team in one of the institutions participating in the FIBRE-BR efforts. The responsibility of this team is the evaluation of the issues raised and being able to redirect all relevant events for each island.

  Discussion: This level should be operating during Brazilian business hours, and is expected to be undertaken by RNP. The response time expected should be no more than 1 business day. It should be staffed by two engineers. Support should be offered in both English and Portuguese languages.

- Level 2

  To be offered in a distributed fashion by a team at each island. The responsibility of this level is the handling of incidents of the local island.

  This level should be operating in Brazilian business hours. The response time expected should be no more than 3 business days. It SHOULD be staffed by two engineers. Support should be offered in both English and Portuguese languages.

- Level 3

  The third level should be offered in a distributed fashion by the development team. The responsibility of this level is the handling of problems found in the software and/or hardware being used and/or developed.

  This level should be operating during Brazilian business hours. The response time expected should be no more than 5 business days. It should be staffed by two developers. Support should be offered in both English and Portuguese languages.

12.2 Ticketing System

[Req OP03] The FIBRE-BR system MUST use a ticketing system tool as a communication channel to record issues users meet in using the system.
Discussion: A ticketing system is used to manage and maintain lists of issues reported by the users.

[Req OP04] The FIBRE-BR ticketing system SHOULD be accessible to users and to different levels of support, and MUST allow a ticket to be assigned to different teams and/or individuals.

[Req OP05] The FIBRE-BR system MUST be able to send notifications by e-mail and maintain schedules and other timestamps, such as opening and closing times of events. One desirable feature would be the ability to share maintenance calendars of the different islands.

[Req OP06] The FIBRE-BR system MUST be intuitive to use and user friendly.

Req OP07] The FIBRE-BR system SHOULD allow the recording of important events, the definition of workflows and the customisation of forms.

[Req OP08] Relevant information that SHOULD be recorded in the ticketing system will include:

- Island information: primary and secondary contact, IP and / or IPv6 address ranges.
- User information: name, e-mail, institution, reason to access the FIBRE-BR system islands and application information.
- Events: Incidents, Information Requests and Scheduled Maintenances.

12.3 Infrastructure Monitoring

[Req OP09] Every island SHOULD operate a highly operational environment.

[Req OP10] All components of the infrastructure SHOULD be monitored to ensure visibility of the performance of each island.

[Req OP11] During the evolution of the project, targets SHOULD be defined based on the current operational environment.

[Req OP12] A monthly report of the components of each island SHOULD be generated and made available through the project Wiki.

[Req OP13] A centralized monitoring infrastructure SHOULD maintain monitoring information about all elements of each island and generate a monthly report, to be made available through the project Wiki.

[Req OP14] This monitoring infrastructure should monitor the following metrics for each component:

- Availability.
- Downtime.
- Number of Failures.
- MTTR - Mean Time to Repair.
- MTBF - Mean Time between Failures.
- Downtime for Maintenance.
- Availability (ignoring downtime during scheduled maintenance).

12.4 Traffic register

[Req OP15] The FIBRE-BR system MUST provide the means for researchers to identify, define and choose specific flows and monitored nodes in a categorised way, offering filtering by node local, node model, traffic type, etc.

[Req OP16] The FIBRE-BR system MUST provide the means to classify traffic registers (logs) as active or passive traffic. Passive traffic is a genuine use of the facility with no specific testing purpose, while active traffic is data generated for a specific experiment.

Discussion: Traffic logs generated by one experiment can interfere and/or penalise other experiments.

[Req OP17] The FIBRE-BR system MUST provide the means to discover whether other experiments are in progress at a given time.

[Req OP18] The FIBRE-BR system MUST provide a single screen with all scheduled experiments, and MAY provide the means for researchers to share their logs and results online.

[Req OP19] The FIBRE-BR system MUST provide the means for researchers to schedule their experiments by the selection of a minimum set of parameters.

[Req OP20] The FIBRE-BR system MUST generate logs in open source format.

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